General Aviation

Technically Advanced Aircraft

FAA – Industry

Safety Study

Final Report of

TAA Safety Study Team

August 22, 2003

Table of Contents

Study Team Members 3
Executive Summary 4
Team Findings: 6
Team Recommendations: 6
I. Introduction 9
A. Background: Safer Skies Agenda 9
B. Technically Advanced Aircraft Defined 9
C. Motivation for TAA Safety Study 10
D. Related Safety Activities 11
II. TAA Safety Study Description 11
A. Study Goal and Objective 11
B. TAA Safety Study Team 11
C. Study Methodology 12
D. Explanation of Intervention Evaluations 14
E. Related Reports Reviewed 16
III. Context of Analysis/Interventions: Industry/FAA Safety Goals 16
IV. Findings 17
V. Recommendations: Accident Root Causes and Interventions 19
Appendix A: Charter 29
Appendix B: Case Overview 31
Appendix C: Sample Data Summary 32
Appendix D: Sample Event Sequence and HFACS Summary 33
Appendix E: Sample Root Cause and HFACS Analysis 37
Appendix F: HFACS Classifications 51
Appendix G: Interventions List and Description 55
Appendix H: Sample Individual Evaluation Form 63
Appendix I: Team Evaluation Summary 66

Study Team Members

Co-Chairs

Paul Fiduccia. President, Small Aircraft Manufacturers Association (SAMA).

Robert Wright. Division Manager, General Aviation and Commercial Division, Flight Standards Service, Federal Aviation Administration (FAA)

Members

Frank Ayers. Primary Investigator, FAA/Industry Training Standards Development Team, Embry Riddle Aeronautical University

Jeff Edberg. Director of Operations (Flight Training), Cirrus Design Corp.

Lowell Foster. Aerospace Engineer, Small Airplane Directorate, FAA

Michael Henry, Deputy Division Manager, General Aviation and Commercial Division, Flight Standards Service, FAA

Chuck Hubbard. Vice President, Falcon Insurance

Bruce Landsberg. Executive Director, AOPA Air Safety Foundation.

David Nelson. Claims Manager, Global Aerospace, Inc.

Michael Radomsky. President, Cirrus Owners and Pilots Association.

Dana Siewert. Director of Safety, University of North Dakota.

David Wright. Director of Training, AOPA Air Safety Foundation…

Executive Summary

This Technically Advanced Aircraft (TAA) Safety Study was performed for the same reason as the previous FAA / Industry safety studies conducted under the FAA's Safer Skies Focused Safety Agenda (Safer Skies) – to reduce the fatal accident rate in U.S. civil aviation. This study employed the same methodologies as the Safer Skies General Aviation (GA) safety studies of Weather, Controlled Flight Into Terrain (CFIT), and Aeronautical Decision Making (ADM), and was performed by several of the same persons who were responsible for the GA Safer Skies studies. However, the TAA Safety Study differs from these other studies in three major respects:

1. The TAA Safety Study focuses not on all GA aircraft, but rather on a specific segment of general aviation that is large and growing quickly -- aircraft that meet the definition of a Technically Advanced Aircraft (TAA). TAAs are aircraft with a minimum of an IFR-certified GPS navigation system with a moving map display, and an integrated autopilot. Some TAAs also have a multi-function display that shows weather, traffic and terrain graphics. In general, TAAs are aircraft in which the pilot interfaces with one or more computers in order to aviate, navigate, or communicate.

2. Although the Study's findings and recommendations are based on the detailed analysis of specific TAA accidents, it explicitly looks to the future and the safety implications of these accidents for a general aviation fleet dominated by TAAs, rather then being concerned solely with an analysis of historical accident data.

3. The Study also addresses issues regarding a specific type of pilot of TAAs: persons new to aviation who have become GA pilots principally to use TAAs for "GA Scheduled" operations: flights where the pilot has established a schedule that does not permit delays for the routine instrument meteorological conditions (IMC) that often occur over the long distances typical many TAA operations.

This Study was motivated generally by a desire to understand how the new technologies found in TAAs relate to accidents in aircraft that can be identified as TAAs. It was also motivated by initial accident rates in the first aircraft to be clearly identified as TAAs – the Cirrus Design Corporation SR 20s and SR 22s – that were not substantially lower than the accident rates of comparable newly produced non-TAAs, as had been expected. The Cirrus aircraft are the most numerous of TAAs in the fleet today where the aircraft systems are known and meet the definition of a TAA. Older aircraft with retrofitted new avionics cannot be positively identified as TAAs because their avionics are not described in the accident reports, and thus cannot be studied as TAAs. The Study was also motivated by the views of some aviation commentators that the accidents in Cirrus aircraft may be related to some combination of new airplane characteristics, new technologies, and new types of pilots using GA aircraft for transportation. Finally, the Study was motivated by the desire of all it participants to achieve the lowest accident rate possible in TAA's, to take full advantage of the potential safety benefits of TAAs, and to achieve a TAA accident rate well below the average for piston engine GA airplanes.

The Study was conducted in cooperation with the FAA's Center for General Aviation Research, and its FAA / Industry Training System program, with many of the key personnel in these efforts participating on the TAA Safety Study Team (Team). The Team includes FAA offices with the principal responsibility for GA aircraft and operational safety, GA industry trade associations, and organizations concerned with GA safety.

Team Findings:

1. The safety problems found in the accidents studied by the Team are typical of problems that occurred after previous introductions of new aircraft technology and all also reflect typical GA pilot judgment errors found in analysis of non-TAA accidents

2. Previous safety problems similar to those identified in this Study have been remedied through a combination of improved training and, in the case of new aircraft capabilities, pilot screening (i.e., additional insurance company requirements of pilot experience).

3. The predominant TAA-system-specific finding is that the steps required to call up information and program an approach in IFR-certified GPS navigators are numerous, and during high workload situations they can distract from the primary pilot duty of flying the aircraft. MFDs in the accident aircraft did not appear to present a complexity problem. The Team also believes that PFDs, while not installed in any of the accident aircraft and just now becoming available in TAAs, similarly are not likely to present a complexity problem.

4. TAAs provide increased "available safety", i.e., a potential for increased safety. However, to actually obtain this available safety, pilots must receive additional training in the specific TAA systems in their aircraft that will enable them to exploit the opportunities and operate within the limitations inherent in their TAA systems.

5. The template for securing this increased safety exists from the experiences with previous new technology introductions –the current aircraft model-specific training and insurance requirements applicable to high-performance single and multi engine small airplanes. However, the existing training infrastructure currently is not able to provide the needed training in TAAs.

6. Effective and feasible interventions have been identified, mostly recommending improvements in training, and effective implementation mechanisms for the recommended interventions exist. Therefore, TAA safety problems can be addressed, and the additional available safety of TAAs to address traditional causes of GA accidents can be realized as well.

Team Recommendations:

Training/Procedures: Improve training systems and content for TAAs, including TAA-specific procedures and risk management.

Root Cause: The traditional GA training system has inadequate methods, does not specifically include training to exploit the additional safety opportunities of new technologies or to operate within the limitations of these technologies, and does not include training on how to make accurate flight risk assessments and manage flight risk properly.

Intervention Strategy: Determine and then adopt overall requirements for effective TAA training. Include in TAA training programs procedures for maximizing the available safety benefits of TAA systems and operating within their limitations, and for making optimal flight risk assessments and managing flight risk.

Training System Methods. Realistic, Scenario-Based; Simulation-Based; Integrate "Basics" with TAA Competence; Train and Test to Competence in flying both the "Physical Airplane" and the "Mental Airplane" (See section 1.1.5 for the definitions of these terms), and in Risk Assessment and Management.

TAA Opportunities Training. Competence in Key Functions; Supplemental Self-Training; Address Traditional Accident Causes.

TAA Systems Limitations Training. Avoid Over-Estimating TAA Capabilities; Understand Inherent TAA Limitations; Understand Coupled Pilot and Aircraft Limitations; Understand the combined Pilot / Aircraft Requirements for "GA Scheduled" Operations.

Risk Assessment and Management. Selection of TAA Systems and Pilot Capability; Training for Low-Experience and Computer-Illiterate Pilots; Risk Assessment and Management Best Practices; Pilot Ethics – Professionalism;

Technology: Increase the use of technology to address accident causes.

Root Cause: Most TAAs in the fleet, especially retrofits, do not incorporate all new technologies that could assist pilots in securing all available TAA safety to avoid traditional accident causes. Most TAAs do not incorporate systems that would help pilots to recognize potential hazards (e.g., weather, traffic, terrain), to understand the status of the aircraft automation and systems, and to easily configure for their specific preferences and easily operate key navigational and flight control functions.

Intervention Strategy: Manufacturers should make available, and TAA owners should install, systems to improve the pilot's awareness of hazards to flight and the status of automation systems, and to simplify the process of executing IFR approaches.

Hazard Displays. Weather Hazard Displays; Terrain Awareness and Warning Displays; High Density Altitude Warning System, Insufficient Fuel Warning System. This includes both availability in the aircraft and automatic pilot alerting when hazards exist.

Automation and Aircraft Systems Status Indications. Providing pilots with unambiguous indications on autopilot and GPS navigator mode status.

Simplified IFR-Certified GPS Navigator Operation. Next generation GPS Navigators that are simpler to operate and have standardized basic operations.

Pilot-Specific Avionics Configuration Setting. Enable return to pilot-specific avionics setting when multiple pilots use aircraft.

System Safety Approach: Coordinated implementation by all major players.

Root Cause: The success of any of the recommended interventions above depends on the extent to which they are accomplished, including the dissemination of training and the improvement and enhanced use of technology.

Intervention Strategy: The interventions recommended above should be implemented through the combined and coordinated actions of: TAA Pilots and Owners; Manufacturers of TAA Aircraft and Avionics; Training Organizations; Ground and Flight Instructors; Pilot Examiners; Insurers; Owner-Pilot Organizations; Shared Ownership Organizations; Accident Investigators; The FAA, and Organizations that can communicate to GA pilots and owners.

I. Introduction

A. Background: Safer Skies Agenda

To minimize United States (U.S.) aviation fatalities and reduce the fatal accident rate in US civil aviation, it is necessary to address the causes of fatal accidents in general aviation (GA) aircraft, which comprise more than 90% of the US civil aviation fleet. The FAA's Safer Skies Focused Safety Agenda (Safer Skies) has already addressed historical causes of general aviation accidents through the Weather, Controlled Flight Into Terrain (CFIT), and Aeronautical Decision Making (ADM) Joint Safety Analysis Teams (JSATs) and Joint Safety Implementation Teams (JSITs), and the continuing work through the General Aviation Joint Steering Committee (GAJSC) to monitor the progress on the implementation of the recommendations of these groups.

As a new generation of technically advanced aircraft (TAA) come into the GA fleet, along with new pilots with less experience whose primary motivation for flying is to use small aircraft for transportation (rather than recreation), additional accident interventions must be developed to maintain GA safety. This emerging category of GA aircraft present new safety opportunities that could enhance GA safety, but it also offers new safety challenges. This Report is a first step in addressing safety prospectively, before a great number of accidents occur, and targeting a specific segment of general aviation.

B. Technically Advanced Aircraft Defined

Although the definition of a technically advanced aircraft (TAA) is not completely settled, this term is intended to identify aircraft that are sufficiently different from traditional GA aircraft, which were previously studied by Safer Skies, such that new and different types of safety "interventions" may be required to reduce accidents in these aircraft. "Interventions" are corrective actions that are intended to address an identified accident cause or type of error, and thus "intervene" between these causes and an adverse effect leading to an accident For the purpose of this study, a TAA is defined as an aircraft that has at a minimum:

- IFR-certified GPS navigation equipment (navigator) with moving map; or
- A multi-function display (MFD) with weather, traffic or terrain graphics;
- An integrated autopilot.

In general, TAAs are aircraft in which the pilot interfaces with one or more computers in order to aviate, navigate, or communicate.

Additional significant factors associated with TAA operations are:

- A high-capability airframe – one that is somewhat faster than traditional GA small aircraft and is comfortable enough to induce many pilots to take long-distance trips, where multiple weather systems and different types of terrain will most likely be encountered. This type of GA operation is the most demanding of pilot knowledge, skill and judgment.

- A single, non-commercial pilot as crew, who is often a new aviator with few years (or even months) of involvement in general aviation, with low total flying time, and often without an instrument license.

TAAs are a substantial, and rapidly increasing, percentage of the GA fleet. Most TAAs are older, traditional GA airplanes that have undergone a transformation through substantial navigation, communication, and display system (avionics) upgrades. In addition, "new-production" TAAs, such as the Cirrus Design Corporation (Cirrus) SR 20 and SR 22 and The Lancair Company (Lancair) Columbia 300, are entering the fleet in increasing numbers.

C. Motivation for TAA Safety Study

Some aviation commentators have suggested that accidents in the most numerous of the new TAAs (Cirrus SR 20 and SR 22) may be related to some combination of new aircraft capabilities or characteristics, new avionics, or new types of pilots using small aircraft for transportation. The new aircraft capabilities are those that increase the likelihood that single piston engine small airplanes will be used for long-distance transportation. The new avionics include IFR-certified GPS navigators, MFDs, and integrated autopilots. The new pilots are those who have recently been attracted to general aviation by the prospect of being able to use small airplanes for reliable transportation with greater ease of use, speed, and comfort than similarly priced airplanes of the past.

The GA industry and the FAA want to address any emerging safety issues with TAAs now, before a majority of the fleet becomes TAAs, rather than waiting for a long history of TAA accidents to be created (i.e., to be more proactive rather than reactive). We also want to secure all of the available safety benefits of TAAs as soon as possible.

For these reasons, an FAA / Industry TAA Safety Study Team (Team) was assembled by the General Aviation and Commercial Division of the FAA, the FAA Small Airplane Directorate, and the Small Aircraft Manufacturers Association. The goal of the Team is to identify effective and feasible interventions to TAA accidents, and thus to secure, to the maximum extent possible, the available safety benefits that are intended and expected to be provided by the new technologies found in TAAs.

D. Related Safety Activities

This Safety Study was conducted in coordination with the FAA's General Aviation Center of Excellence, and the Center for General Aviation Research (CGAR), which is developing improved training materials for TAA pilots. The principal members of the CGAR, Embry Riddle Aeronautical University and the University of North Dakota, are also members of the Team. FAA directs the CGAR through the General Aviation and Commercial Division (AFS 800) of the FAA Flight Standards Service. The training materials under development by CGAR include model syllabi for initial and recurrent pilot training, ab initio training, and instructor training.

Another related effort is the FAA / Industry Training Standards (FITS) program, also directed by AFS 800. This is the principal program for FAA to implement the recommendations of the Safer Skies ADM JSAT, and for implementing the CGAR products. The FITS program is broadly supported by the GA industry, with several "launch customers" among manufacturers, training organizations, and shared ownership providers. FITS will be used to implement the products of CGAR, and the recommendations of this Safety Study.

II. TAA Safety Study Description

A. Study Goal and Objective

Goal: Significantly reduce the rate of fatal TAA accidents, and enable TAA pilots to derive the maximum amount of the available safety from TAAs.

Objective: Produce a set of interventions that achieves this safety goal, while maintaining or improving the "capacity – utility" and "efficiency – affordability" of GA TAA operations.

B. TAA Safety Study Team

Team members were selected based on their organizational affiliation, their operational experience, and their technical expertise in specific areas such as: flight operations, flight training, insurance underwriting standards, aviation human factors, weather accidents, new avionics and ground systems. Almost all team members were pilots with varying levels of operational experience.

The TAA Safety Study Team is composed of 13 members:

- FAA Co-Chair, the Division Manager, as well as the Deputy Division Manager, and the Manager of Aviation Inspector Operations, of the General Aviation and Commercial Division, Flight Standards.

- Industry Co-Chair, the President of the Small Aircraft Manufacturers Association.

- An Aerospace Engineer from the FAA Small Airplane Directorate, who was one of the core Team members.

- Two insurance industry claims, accident and safety experts.

- The Primary Investigator of the FAA Industry Training Standards Development Team, and the Safety Manager of the leading 4-year flight training institutions, Embry Riddle Aeronautical University and the University of North Dakota.

- The Executive Director and Director of Training of the AOPA Air Safety Foundation.

- The President of a TAA owner/pilot association, the Cirrus Owners and Pilots Association.

- The Director of Operations and Training of a TAA manufacturer, Cirrus Design Corporation.

The Team had the full cooperation of the National Transportation Safety Board (NTSB), which provided it with complete factual reports on all of the accidents selected for examination.

One Team member had been FAA Co-Chair of the FAA/Industry Safer Skies Joint Steering Committee; Two of the Team members had previous experience as Chairs of a Safer Skies JSAT (one of Weather and on of CFIT), one was also the Chair of the Safer Skies GA Weather JSIT, and one had been a member of the ADM JSAT.

C. Study Methodology

The method used by the Team to accomplish this objective is an in depth analysis of TAA accidents using the methodology of the Safer Skies Agenda's Joint Safety Analysis Teams (JSATs) for Weather, CFIT and Aeronautical Decision Making (ADM). This analysis includes a "root cause analysis" used in the Weather and CFIT JSATs and the Human Factors Aviation Classification System (HFACS) of error analysis developed by FAA's Civil Aero Medical Institute and employed in the ADM JSAT.

This process proceeded along the following seven steps:

1. <u>Accidents were selected for analysis</u>. The criteria for selection were:

- The avionics installed in the aircraft had to be positively determined to ensure that the aircraft meet the definition of a TAA.
- The accident had to be classified as “fatal”, “serious”, or otherwise “unique to TAAs”.
- The factual report of the accident had to be sufficiently thorough and detailed to enable the Team to perform an in-depth root cause analysis.

Based on these criteria, 11 accidents were selected for analysis, 10 involving Cirrus airplanes and 1 involving a Lancair airplane. **See Appendix B for a listing and overview of the accidents analyzed**.

These 11 accidents (of which 6 were fatal) were in 6 different categories:
- 4 non-instrument-rated pilot, VFR-into-IMC (3 fatal).
- 3 approach to landing, controlled flight into terrain (CFIT) (2 fatal).
- 1 takeoff at high-density altitude (1 fatal).
- 1 maneuvering flight (stall maneuvers) (1 fatal).
- 1 mechanical failure due to improper maintenance (with the successful use of airframe parachute – no injury).
- 1 loss of control during landing (1 non-fatal, injury)

2. The complete NTSB factual file was reviewed (including NTSB data collection forms, witness statements, radio communications transcripts, maps, weather reports, accident narratives, radar track data, and in one case the equivalent of flight data recorder information. Since the NTSB has not publicly released the fact files in some cases, and has not completed its investigations, we have redacted the identifying information from the Appendices for cases in which final reports have not been issued. Aeronautical charts, weather information, including freezing levels and cloud bases and tops, and all other available information relevant to the accident were used to reconstruct the accident flights.

3. A set of three summary documents was prepared for each accident by one industry and one FAA participant:

- Data Summary, containing key information on each accident, including all of the pertinent information on the pilot, the aircraft, the mission, the weather conditions, accident type, and various fact issues. See Appendix C for a sample.

- Event Sequence and HFACS Category, containing a chronological sequence of each of the events regarding the accident, based on the review of all available information (NTSB and company). This document also states the HFACS categories of any errors found in each event. See Appendix D for a sample of this document; see Appendix F for a description of the HFACS categories.

- Root Cause and HFACS Analysis, containing a Key Fact Summary, an Inference – Evidence Summary table, an Inference Description of Flight (a narrative description of the key elements of the flight as inferred from all the evidence), at Root Cause Analysis (performed in the same way as in Safer Skies Weather and CFIT JSATs), an HFACS analysis (performed in the same way as in the Safer Skies Aeronautical Decision Making JSAT), and a Potential Interventions list with analysis of their applicability in this accident. See Appendix E for a sample.

4. The Team meeting as a group finalized these documents by applying their combined judgment to the analysis of each accident. (Note: During the Team Meeting, it was determined that two of the accidents were really not "TAA" accidents, i.e., the avionics systems in the aircraft were not relevant to the accident even though they were present in the accident aircraft.) The Team determined its cause-effect relationships, root causes, HFACS categories, and developed its interventions, and recorded them in the Root Cause and HFACS Analysis documents for each accident.

5. The interventions developed by the Team for all the accidents were grouped according to root cause and HFACS category, and interventions that addressed the same systemic causes were combined and generalized. The resulting Interventions List grouped and sorted these interventions into categories, with notations referencing the accidents in which they were found. See Appendix G.

6. Each Team member individually completed an evaluation form on Effectiveness and Feasibility. See item D. below for an explanation of the evaluation process, and see Appendix H for a sample completed evaluation form.

7. The Team then met again and jointly evaluated all of the interventions. Team members presented their reasons for their evaluations, and through discussion, consensus was reached on the evaluations. See Appendix I for the Team Evaluation Summary.

D. Explanation of Intervention Evaluations

Each intervention was evaluated for both effectiveness and feasibility, first by each Team member individually, and then by the Team meeting together to reach consensus. Both effectiveness and feasibility were evaluated as one of three levels: a score of 3 for high, 2 for moderate, and 1 for low.

Effectiveness was defined as the probability that the intervention would be effective in addressing the root cause of the accidents studied, as well as for TAA pilots and accidents in general. An intervention was determined to be High Effectiveness if it would improve pilot decision making through better assessment of the risk of the current flight plan and, in most cases, would intervene between an accident root cause and an accident occurrence. A determination of High

Effectiveness also requires that typical pilots with typical training could employ the intervention properly. In general, the level of effectiveness depends on what percentage of pilots would be provided what degree of increased safe-utility in TAAs by its implementation.

Feasibility was defined as the probability that the intervention could be implemented properly. Feasibility was divided into four subcategories: Technical, Financial, Regulatory and Operational.

- <u>Technical Feasibility</u> was assessed against the current state-of-the-art and the expected availability of the intervention within three years. The three-year time period was set because one of the Safety Study Goals is to address these accidents quickly, before rapidly increasing numbers of TAAs cause them to become a majority of the GA fleet. High Technical Feasibility is found where there is no technical risk of implementing the intervention within this time period. Moderate Technical Feasibility is found where there is moderate technical risk, and Low Technical Feasibility where there is high technical risk of implementing the intervention within 3 years.

- <u>Financial Feasibility</u> was assessed as the percentage of TAA pilots who could afford and were likely to take advantage of the intervention. The Team noted that TAA aircraft owners have already installed approximately $20,000 worth of TAA avionics. High Financial Feasibility is found where more than 75% of the pilots of TAAs were estimated to be able to afford the intervention. Moderate Financial Feasibility is found where 25 – 75% of TAA pilots could afford it, and Low Financial Feasibility is found where less than 25% of TAA pilots could afford the intervention.

- <u>Regulatory Feasibility</u> was assessed for aircraft operations conducted under Part 91 of the Federal Aviation Regulations (FARs). . High Regulatory Effectiveness is found where no new FAA documents (e.g., Rule, Advisory Circular, Order, etc.) need be produced. Moderate Regulatory Feasibility exists where only policy documents would have to be changed, and Low Regulatory Feasibility exists where a rule change is needed (almost always requiring several years to complete).

- <u>Operational Feasibility</u> was assessed based on how easy it would be to implement this intervention within the current National Airspace System (NAS). High Operational Feasibility is found where no change in the NAS is required to operate the intervention, Moderate Operational Feasibility where moderate NAS changes are necessary, and Low Operational Feasibility where major NAS change is necessary.

A composite Feasibility Value was calculated as the median value of the four feasibility subcategory values. In general, if an intervention would use off-theshelf technology (or technology known to be in development and confidently expected to be available within three years), was affordable to the largest part of TAA aircraft owners and pilots, would not require FAA policy change, and would not require a change in NAS procedures, it was assessed as Highly Feasible.

Technical and financial feasibility were assessed separately for new TAAs and retrofit TAAs, because of the substantially different impact of these two subcategories according to this classification of aircraft.

The interventions recommended in this report all ranked "High" in both effectiveness and feasibility for new TAAs, but many of these ranked low in some categories for retrofit TAAs. This is because the higher monetary value of new TAAs compared to retrofit TAAs makes it much more likely that owner/pilots of new TAAs would invest in the recommended training and technologies to secure the safety benefits that are provided by the technology in their TAA.

E. Related Reports Reviewed

Some Team members also reviewed the previous Safer Skies reports, on Weather, CFIT, and Aeronautical Decision Making, and reviewed previous studies on similar aircraft, where new designs were a departure from the norm and encountered an initially higher accident rate. The information reviewed for this portion of the Study was:

- Safety Review, Mooney M20 Series, Models M20 through M20M, AOPA Air Safety Foundation, 1995.
- Safety Review, Piper Malibu Mirage, Model PA-46, AOPA Air Safety Foundation, 1994.
- Safety Review, Beechcraft Bonanza/Debonair, Models 33, 35e, and 36, AOPA Air Safety Foundation.
- Safety Review, Cessna P210, AOPA Air Safety Foundation, 1992.

III. Context of Analysis/Interventions: Industry/FAA Safety Goals

The FAA's strategic goals are generally stated as: Safety, Capacity, and Efficiency. The goals of the GA industry and FAA regarding TAAs are the same, and intervention recommendations must be developed with this in mind.

Safety: The current GA fatal accident rate is 1.22 per 100, 000 flight hours, and this rate has generally declined for the past several years.[1] The FAA/Industry

[1] AOPA ASF 2002 Nall Report, p. 1.

goal for catastrophic system failures in single piston engine airplanes is one event per million flight hours, and this may be a goal to which GA can aspire for combined pilot and system failures in TAAs.

Capacity – Utility -- Reliability: For GA, this goal relates to the utility of the airplane and pilot together in being able to accomplish the desired mission on the pilot's schedule, and reliability in actually doing so in the prevailing weather conditions. It can be measured by what percent of the year the aircraft can be operated safely for its intended mission. TAA systems are intended to increase utility and reliability of small aircraft by providing pilots with enhanced information on their location relative to airports and navigation aids, and relative to potentially hazardous weather, terrain, and traffic. They also provide enhanced information on aircraft systems' operation and reduce pilot workload through the use of autopilots and other flight aids.

Efficiency - Affordability: For GA, this goal relates to reduced acquisition, operational and training costs for a given level of safety and capacity. TAA systems are intended to increase GA efficiency through the application of new technologies.

IV. Findings

The Team made the following findings based on its analysis.

1. The TAA safety problems analyzed in these accidents are typical of previous new aircraft technology introductions. Several previous aircraft that incorporated new technology, new aircraft flight characteristics, or that enabled private pilots to increase their altitude and range capabilities initially had lower safety rates. These aircraft include the Cessna 177 Cardinal, Piper PA-46 Malibu, and Robinson R-22.

2. These initial safety problems were remedied after problems were identified and addressed through training system modifications to address differences in the new aircraft, and through pilot screening, accomplished through insurance company requirements for flight experience and training accomplishment.

3. The predominant TAA-system-specific finding is that the steps required to call up information and program an approach in IFR-certified GPS navigators are numerous, and during high workload situations they can distract from the primary pilot duty of flying the aircraft. MFDs in the accident aircraft did not appear to present this problem. In addition, the Team believes that PFDs, while not installed in any of the accident aircraft and just now becoming available in TAAs, similarly are not likely to present this problem.

4. TAAs provide increased “available safety”, a potential for increased safety rates that can be exploited by pilots, increased ease-of-use (except for the earlier generation IFR GPSS navigators), and reduced workload over the life of the airplane. However, for pilots to access this increased available safety, they must initially undertake additional training to understand both the ways to exploit the safety opportunities inherent in TAA systems, and their inherent limitations.

5. The general template exists for enabling pilots to extract this available safety – training and screening systems similar to current aircraft model-specific training on high-performance single and multi-engine, small airplanes, such as the Mooney, Bonanza and Malibu. . However, the existing training infrastructure currently is not able to provide the needed training in TAAs. This infrastructure included training methods, TAA-specific training syllabi, and instructors capable of TAA-specific training.

6. Effective and feasible interventions have been identified in this Report, and effective implementation mechanisms appear to exist, leading the Team to conclude that TAA safety problems can be effectively addressed and the additional available safety of TAAs can be realized.

V. Recommendations: Accident Root Causes and Interventions

The Team's recommendations are in the following areas: Training, Technology & Procedures, and System Safety Implementation Approach.

1. Training/Procedures: Inadequate training systems and lack of defined procedures for TAAs.

> **Root Cause:** The traditional GA training system has inadequate methods, does not specifically include training to exploit the additional safety opportunities of new technologies or to operate within the limitations of these technologies, and does not include training on how to make accurate flight risk assessments and manage flight risk properly.

Intervention Strategy: Determine and then adopt overall requirements for effective TAA training. Include in TAA training programs procedures for maximizing the available safety benefits of TAA systems and operating within their limitations, and for making optimal flight risk assessments and managing flight risk.

1.1. **Training System Methods**.

1.1.1. **Realistic, Scenario-Based.** Training, both on the ground and in the aircraft, should be based on typical GA transportation operations scenarios, with an emphasis on situations that have traditionally caused fatal accidents, including abnormal operations. For example, a non-instrument rated pilot flying into marginal visual metrological conditions (MMFR) in mountainous areas that become instrument meteorological conditions (IMC), or a new instrument rated pilot receiving last-minute approach clearance amendments coupled with an erroneous tower frequency.

1.1.2. **Simulation-Based.** Overall TAA training should rely greatly on various levels of simulation, beginning with a computer-based part-task trainer for each major TAA system on the aircraft, and moving up to an integrated cockpit simulator for scenario-based training. These should be available on CDs for home use on personal computers.

1.1.3. **Integrate "Basics" with TAA Competence.** TAAs do not currently provide sufficient pilot assistance or automation to eliminate any traditional pilot knowledge, skill or judgment requirements. In addition, as the fleet transitions to TAAs, pilots must have the capability to fly in non-TAAs. Therefore, TAA training must continue to train in the "basic", fundamental flying skills necessary for pilots of non-TAAs, which provide information necessary to supplement that available for TAA systems, while also training for TAA competence. This means that total training requirements for TAA pilots (in terms of what pilots need to know, not hopefully the time it takes them to learn) currently are greater than for non-TAA pilots. This investment in additional initial and recurrent training time is believed to provide a high rate of return over the lifetime of use of TAAs, because of the increased safety, reliability and efficiency that can be derived from TAAs compared to non-TAAs.

1.1.4. **Train and Test to Competence.** TAA training should be done to defined performance standards, and pilots should be trained and tested to these standards, with clear indications of pass or fail. Simply completing a defined time period of training is not adequate. Pilots must recognize that TAAs require additional training, and be willing to get this training, in order to receive the far greater benefits that TAA aircraft can provide.

1.1.5. **Competence in flying both the "Physical Airplane" and the "Mental Airplane", and in Risk Assessment and Management.** The training must create in the pilot competence in three critical, and very different, areas.

1.1.5.1. The "Physical Airplane" is the airframe and its operating systems (flaps, landing gear, environmental control, lights, etc.). This includes take offs and landings in airplanes with higher wing and power loading, laminar flow wings and airframes, and generally higher-performance airplanes, with kinematics and flight characteristics different from low-performance single piston engine airplanes typically used for training and recreational flying. These are traditional, fundamental" stick and rudder" skills, the lack of which does not often lead to fatal accidents, but that does often lead to accidents and incidents that are in themselves expensive, and may also interfere with the pilot's ability to master the "Mental Airplane".

1.1.5.2. The "Mental Airplane" is the combination of avionics systems used for communication, navigation, surveillance and flight control. It includes that ability to utilize the key functions of each avionics system individually, and to properly utilize the key functions that rely on the integration of multiple avionics systems, such as IFR GPS navigator, autopilot, MFD with moving map, and electronic flight information system (EFIS) display or primary flight display/navigation display (PFD/ND). TAA Opportunities Training and TAA Systems Limitations Training (below) detail these training elements. This training includes providing pilots with a disciplined and standardized approach to their flying because of the larger number of capabilities and configurations of TAAs.

1.1.5.3. Risk assessment and risk management is a separate skill and element of training, although it relates strongly to training in the skills necessary to derive all TAA safety Opportunities and to operate within TAA Limitations. Proper risk assessment and risk management produces a high level of safety. When coupled with the other training elements that create competence in the use of TAA systems, risk assessment and management skills enable a pilot to simultaneously extract the maximum available safety, utility and efficiency from a TAA.

1.2. **TAA Opportunities Training.** Train TAA pilots to exploit all of the safety and utility benefits of their TAA systems.

1.2.1. **Competence In Key Functions.** TAA pilots must be competent to fly their “Mental Airplane”, at the same time they are flying the “Physical Airplane.” The training must identify what tasks are required for “Mental Airplane” competency (which is not every function available on each avionics system), so performance standards can be established. Pilot training can then be conducted to meet or exceed the “Mental Airplane” performance standards, as well as general “Physical Airplane” task management. The key functions are those that are time critical in that the pilot cannot decide easily to simply “do later” when there is more time, and include functions such as IFR GPS approach operation. This training would include not only the “knobology” (knob twisting and button pushing) of each avionics system, but also the way it should be used in actual operations. It also would address the correct interpretation of weather graphics (including the meaning of the color coding scheme used), as well as terrain and traffic displays. This training would also include any novel features of the airplane, such as the use of an airframe parachute system.

1.2.2. **Supplemental Self-Training.** TAA training systems should enable pilots to “self-train” on upgraded avionics features, including manufacturer information on proper use and limitations. These could be considered “options” training, on non-standard system configurations.

1.2.3. **Address Traditional Accident Causes.** TAA training should include procedures that employ TAA-specific systems to address traditional GA accident causes, such as using the autopilot and MFD to make a 180-degree turn away from terrain when inadvertent IMC is encountered.

1.3. **TAA Systems Limitations Training.** Train TAA pilots to understand the inherent limitations of their TAA systems, and not degrade safety by over-estimating the capabilities of their TAA systems and misusing them.

1.3.1. **Avoid Over-Estimating TAA Capabilities.** TAA training should make it clear that TAA systems do not replace the entire Instrument Flight Rules (IFR) system, and are not substitutes for good basic airmanship skills and good aviation judgment. Pilots should be instructed on the layered, and interdependent protections of the IFR system – which include interrelated certification standards, operational procedures and pilot training requirements – and how TAA systems used under Visual Flight Rules (VFR) do not replace the IFR system at nearly the same level of safety as the entire IFR system provides.

1.3.2. **Understand Inherent TAA Limitations.** TAA training should include sufficient technical details of TAA system reliability to make clear to pilots why operating limitations are applied. These limitations would include.

1.3.2.1. Lower GPS reliability because of terrain masking of satellites when aircraft are operated at low altitudes in mountainous areas.

1.3.2.2. Inaccuracies in terrain data away from major airports where it has been verified in TAWS system databases.

1.3.2.3. Slow weather forecast and diagnostic update rates, delays in weather product transmission to the aircraft, limitations in the accuracy and precision of forecasts, and difficulties in pilot interpretation of weather information. These problems are worsened when coupled with the limited weather tolerance of most TAA airframes (relatively low climb rates, speed, range, endurance, and ice protection capability).

1.3.2.4. Accuracy and coverage limitations specific to various types of traffic awareness systems.

1.3.3. **Understand Coupled Pilot and Aircraft Limitations.** TAA training should make clear the pilot's limitations, in terms of ratings, experience, and currency, coupled with TAA system limitations (see above), and that safety is the result of respecting the capabilities and limitations of the pilot-aircraft combination compared to the mission requirements. Scenario training should demonstrate how accidents result from a failure to understand and observe these limitations, i.e., “how to have a potentially fatal accident by misusing TAA avionics.”

1.3.4. **Understand the Pilot -- Aircraft Requirements for “GA Scheduled” Operations.** TAA training should emphasize that for personal and business transportation where the schedule set by the pilot (or a passenger) must be met to successfully complete the mission, i.e., for a “GA Scheduled” operation, the pilot-aircraft combination must be capable of reliable operations despite routine IMC conditions. This means that unless the pilot can delay the trip, even for a few days, in order to wait for good VMC weather with no loss in utility, both pilot and aircraft must be IFR capable. TAA training must make clear that the TAA does not change this fact of aviation operations.

1.4. **Risk Assessment and Management.** TAA training to understand the risks and risk mitigations for fast, long-distance “GA Scheduled” operations. While risk assessment and management are the keys to safety in the operation of any aircraft. However, for TAA pilots, this training also should address the potential to incorrectly conclude that the greatly increased TAA capabilities automatically translate into a great increase in the pilot’s abilities to safety accomplish all missions.

1.4.1. **Selection of TAA Systems and Pilot Capability.** Risk training should include incorporation in the aircraft of the specific systems (e.g., storm avoidance, ice protection) and the additions of specific pilot capabilities (instrument license, mountain flying training) necessary to safety accomplish the mission. It would also include an explanation of the safety challenges posed by aircraft that are fast and and suitable for traversing long distances and encountering multiple weather systems and terrain types in a single flight.

1.4.2. **Training for Low-Experience and Computer-Illiterate Pilots.** Pilots new to aviation, with a small number of years in aviation (and thus less opportunity to learn by personal experience and by experience of other pilots (”by osmosis”) and limited total hours, and pilots who are not comfortable with computers, have special training needs that must be addressed through add-on training modules. Training programs must provide additional time for these pilots to meet the performance standards.

1.4.3. **Risk Assessment and Management Best Practices.** Training should include the use of a risk assessment methodology, such as the FITS Weather and Personal Risk Assessment Guide. This includes setting personal weather minimums, using best practices for weather briefing and planning, including having an alternative plan of action prepared in advance (a “Plan B”), and continuously monitoring the flight for the conditions that would “trigger” activating Plan B.

1.4.4. **Pilot Ethics – Professionalism.** Doctors and lawyers are charged with ethical responsibilities because of their access to a specialized body of knowledge inaccessible to the layman, which forces their patients and clients to rely on their skill and judgment. Pilots have similar responsibilities to their passengers, who are not capable of judging the safety of a flight based on the capabilities of the pilot and airplane to accomplish the mission safely. Pilots should be trained in exercising this ethical responsibility to their passengers by resisting pressure to make unsafe flights, even with highly capable TAAs.

Evaluations: The training interventions were assessed as High Effectiveness and High Feasibility for all TAAs, with the condition that especially for retrofit and second-owner new TAAs, the training be “fast, inexpensive, convenient and incentivized.”

2. Technology: Inadequate use of technologies that could address accident causes.

Root Cause: Most TAAs in the fleet, especially retrofits, do not incorporate all new technologies that could assist pilots in securing all available TAA safety to avoid traditional accident causes. Most TAAs do not incorporate systems that would help pilots to recognize potential hazards, to understand the status of the aircraft, and to easily configure and operate key navigational and flight control systems.

Intervention Strategy: Manufacturers should make available, and TAA owners should install, systems to improve the pilot’s awareness of hazards to flight and the status of automation systems, and to simplify the process of executing IFR approaches. In general, these systems should be designed specifically to be easily and accurately operated by single, owner-pilots.

2.1. **Hazard Displays**. (Joint responsibility of TAA owners and pilots, airframe and avionics manufacturers, and the FAA). Incorporate displays in TAAs of typical hazards to small aircraft operations. These displays should not only be available for the pilot to use, but should also automatically alert the pilot when a hazard exists by showing the relevant information on the display.

2.1.1. **Weather Hazard Displays**.

2.1.1.1. Weather data link and displays. Owners should install a weather data link system, which provides color weather graphics on their multi-function display (MFD) to enable them to access weather hazard information in the air. Such systems enable pilots to be aware of changing weather conditions creating weather hazard areas well before entering these areas.

2.1.1.2. Ceiling and Visibility Graphics. The FAA and National Weather Service (NWS) should attach a high priority to the development for pilot use of graphics showing areas of low ceilings and visibilities, to address the largest cause of fatal weather accidents in TAAs (as well as in non-TAAs) – inadvertent VFR flight-into-IMC. These "area" graphics should be provided along with graphical METARS showing pilots "point" airport conditions that are below their landing minima.

2.1.1.3. Icing Graphics. FAA should make operational for supplemental pilot use (i.e., in addition to icing AIRMETs) icing graphics, such at Current Icing Potential (CIP) and Forecast Icing Potential (FIP).

2.1.2. **Terrain Awareness and Warning Systems (TAWS).** Owners should install TAWS systems (not just some terrain information) in their MFDs. These should be turned on all the time, and should provide visual and audio warnings clearly showing the pilot when he is heading toward high terrain.

2.1.3. Warnings/Decision Aiding

2.1.3.1. **High Density Altitude Warning System.** Avionics manufacturers and TAA OEMs should provide high density altitude information on MFDs. Aircraft with temperature sensors (e.g., a component of air data computers on aircraft with PFDs) should at least provide a density altitude figure on the MFD. More sophisticated systems should provide a high density altitude warning by referencing the aircraft's performance tables, the runway length from the airports data, etc.

2.1.3.2. **Insufficient Fuel Warning System.** Avionics could determine that a change in the routing or unforecast strong headwinds could cause the flight to lack sufficient fuel for arrival at the destination with adequate reserves.

2.2. **Automation and Aircraft Systems Status Indications**. (Joint responsibilities of avionics and airframe manufacturers, and TAA owner s and pilots). TAAs should contain systems that provide pilots with unambiguous indications of whether the autopilot is on or off, that status of trim system operation, the amount of fuel on board, and the operating mode of the GPS navigator (i.e., whether it is tracking to a GPS waypoint or a VOR/Localizer source).

2.3. **Simplified IFR-Certified GPS Navigator Operation**. (Joint responsibility of avionics and airframe manufacturers and TAA owners and pilots). TAAs should have GPS navigators used for IFR approaches that are simpler to operate and which have standardized operation for the most essential approach and en route functions. This will especially help TAA pilots who rent or own multiple aircraft.

2.4. **Pilot-Specific Avionics Configuration Setting.** (Joint responsibility of avionics and airframe manufacturers and TAA owners and pilots). TAA avionics should enable a pilot to easily return the avionics to the configuration he has established, when another pilot using the aircraft may have altered the settings.

Evaluations: Each of these interventions was assessed as High Effectiveness and High Feasibility for new TAAs, and as High Regulatory and Operational Feasibility for both new and retrofit TAAs. These interventions were assessed as Low Effectiveness and Low Technical and Financial Feasibility for retrofit TAAs.

3. **System Safety Approach: Implementation by all major players.**

Root Cause: The success of any of the above interventions depends on the extent to which they are accomplished, including the dissemination of training and the improvement and enhanced use of technology.

Intervention Strategy: The above recommendations should be implemented through the combined and coordinated actions of all the major players in TAA safety.

3.1. **TAA Pilots.** Pilots should adopt a "professional", ethical approach to their flying (See 1.4.4 above). They should get the required training to competence in the "Physical Airplane", the "Mental Airplane", and in risk assessment and management to derive the potential safety and utility opportunities of their TAAs by operating within the limitations of the airplane and themselves.

3.2. **TAA Owners.** Owners of TAAs should be aware of the safety benefits of technologies that can improve safety and incorporate these into their aircraft to the extent economically practical.

3.3. **GA Manufacturers.**

3.3.1. **Aircraft Manufacturers.** Should provide and encourage the use of training programs incorporating the elements in Section 1 above. Should make available the technologies described in part 2 above. Should investigate the installation of systems to record flight data, similar to those in use in all new US automobiles, and perhaps including video and audio recording to assist in accident analysis.

3.3.2. **Avionics Manufacturers.** Should provide training aids in the use and limitations of their products, and should simplify and standardize their operation. Should facilitate accident reconstructions by incorporating subsystems to record button pushes, as well as other flight data, and having these electronics in crash-survivable containers.

3.4. **Training Organizations.** Should incorporate the recommendations listed in Part 1 above.

3.5. **Ground and Flight Instructors.** Should become proficient in the operation of TAA systems and able to teach the items listed in Part 1. FAA and avionics manufacturers should support this instructor proficiency with training syllabi and training aids.

3.6. **Pilot Examiners.** Should become proficient in the operation of TAA systems and able to test the items listed in Part 1.

3.7. **TAA Insurers.** Should provide requirements for the basic level of necessary TAA training to secure insurance, and should provide premium reductions for additional levels of initial proficiency training and recurrent training.

3.8. **Owner-Pilot Organizations.** Should survey their members to understand their characteristics well enough to tailor training materials to them, and should actively participate in and support the dissemination of training systems.

3.9. **Shared Ownership Organizations.** Should survey their owners to understand their characteristics well enough to tailor training materials to them, and should actively participate in the dissemination of training and testing.

3.10. **Accident Investigators.** Should use TAA systems to extract flight data for accident analysis.

3.11. **FAA.** Should develop and disseminate model training materials as defined in Part 1, as well as flight instructor and examiner requirements to be competent in TAAs, and weather product development as provided in Part 2.

3.12. **Organizations that can communicate with GA pilots and owners.** Associations with magazines and web sites should use these resources to communicate information on the best practices of TAA operation, and on the availability of new training systems and content from the FAA, pilot training schools, and other aviation related sources.

Appendix A: Charter

Technically Advanced Aircraft (TAA) Safety Study]
Charter

February 21, 2003

Goal: Maximize the actual operational safety of Technically Advanced Aircraft (TAA) by taking maximum advantage of the technical advances in these aircraft, in an total system safety approach, including new pilot training and testing. TAA is defined as follows:

- <u>New design aircraft</u> with advanced aerodynamics, structures, and systems (such as the Cirrus SR 20 and SR 22 aircraft, Lancair Columbia, and Eclipse 500);

- <u>Operated in an environment of advanced communications, navigation and surveillance</u> (CNS) systems (and integrate via data link with this environment) and participate in new procedures (such as RNP);

- <u>By single-owner-pilots, many of which are new participants</u> in general aviation, attracted by the ability to use small aircraft for transportation.

Objectives of Safety Study:

1. Establish a process for analyzing the TAA accidents that will:
    a. Identify effective interventions, and
    b. Be accepted by the insurance industry, FAA and small aircraft purchasers, as being adequate responses to address the root causes of TAA accidents.

2. Implement these interventions.

3. Coordinate results with FAA FITS activity.

4. Use relevant GA Wx JSAT/JSIT and ADM JSAT recommendations.

Process:

1. Establish a combined Joint Safety Analysis Team/Joint Safety Implementation Team (JSAT/JSIT) in conjunction with the AFS-800 FAA Industry Training System (FITS) program and the Center for General Aviation Research (CGAR). There would be a significant commonality of personnel between the TAA Safety Study JSAT/JSIT, the FITS Oversight Committee and FITS Team, and the GACOE. The JSAT/JSIT would be composed of government and industry experts in small aircraft operations and accident/safety analysis, and would perform the safety analysis and develop potential interventions (as described below).

2. TAA Safety Study JSAT/JSIT Membership:

    - FAA Co-Chair: Robert Wright, AFS-800, Manager, Flight Standards General Aviation and Commercial Division. Manager of the FITS program and CGAR.
    - Industry Co-Chair: Paul Fiduccia, President, Small Aircraft Manufacturers Association; Co-Chair FITS Oversight Committee, Co-Chair of Safer Skies GA Weather JSAT and JSIT.
  - FAA, Flight Standards GA Office: Tom Glista
  - FAA, Small Aircraft Directorate: Lowell Foster.
  - Insurance Broker: Chuck Hubbard, Falcon Ins.

- Insurance Claims: Dave Nelson, AAU Global.
- Flight training: Dana Siewert, Director of Safety, University of North Dakota (UND)
- Flight training: Frank Ayers, Embry Riddle Aeronautical University (ERAU), CGAR
- Safety Analysis: Bruce Landsberg, AOPA/ASF
- Cirrus Owners and Pilots Association (COPA): Mike Radomsky
- Cirrus: Jeff Edburg, Manager of Training.

The TAA Safety Study JSAT/JSIT would employ the Safer Skies JSAT accident analysis method – root cause analysis performed by a government-industry group with sufficient expertise to determine root causes, employing both GA Weather and aeronautical decision making (ADM) and Human Factors Accident Classification System (HFACS) principles and methods, and also checking NASA Aviation Safety Reporting System (ASRS) reports. The main data source will be full NTSB final case files, plus NTSB factual dockets for incomplete investigations, plus any company incident information (where NTSB is not involved), and company information on pilots from training activities. We will keep company accident investigators separate from this program on NTSB cases to avoid jeopardizing any manufacturer's status as a "party" to the investigation.

Appendix B: Case Overview

TAA Safety Study: Case Overview April 30, 2003

Location / Aircraft	Pilot	Mission	Accident
1. XXX	39, CPL, IR, 3215 TT, 620 MM, 11 IFR	XXX night IMC,105 nm	**Approach CFIT**, on night, IFR approach in 300 ft OVC and 3 miles. F. **NOT TAA**
2. **Sierra Vista**, AZ. 4/10/01, SR 20, N116CD. SN 1017 C. ARNAV, Stec 55	PPL, ASEL, NIR, 1450 TT, 116 MM	Tucson - Belen (Albuquerque) Dusk, 310 nm	**VFR-IMC**, CFIT or L/C, icing, gusty winds, turbulence, 150 ft below ridge, at sunset. 3F
3. XXX	PPL, NIR, 256 TT, 12 MM	XXX	**L/C Landing**, after second hard landing on trip home from airplane pickup. NF. **NOT TAA.**
4. **Mitchell**, GA. 8/19/01. SR 22, N232CD. SN 19. B. ARNAV, Stec 55X	49, 15 mos., PPL, ASEL, NIR, 644 TT, 172 MM	Louisville GA to Briscoe (Atlanta), 100 nm.	**VFR-IMC**, L/C then forced landing following thunderstorm and IMC encounter immediately after TO. NF.
5. **Lexington**, KY. 3/16/02. SR 20, N244CD. SN 1140 C ARNAV, Storm, Stec 55.	PPL, ASEL, IR, 371 TT, 110 MM, 24/ 54 act/sim IFR	Lexington KY, practice IFR approaches	**Approach CFIT or Mechanical**, Either loss of AP and TC, or mis-setting of AP, L/C in IMC, precautionary or forced landing, unable CAPS deployment. NF.
6. **Parish**, NY. 4/24/02. SR 22 N837CD. SN 0192 B Avidyne Storm. Stec 55X	P1: Dr. PPL, ASEL, AMEL, IR, 337 TT, 31 MM. P2 PPL, ASEL, IR, 475 TT, 20 MM.	Syracuse NY, Oswego NY; maneuvers en route.	**Maneuvering**, L/C following multiple stalls, flat spin to ground. No CAPS deployment. 2F.
7. XXX	58, 25 yrs flying, CPL, AMEL, IR, 1450 TT, 100 MM.	XXX 700 nm, day.	**Takeoff High Density Altitude.** 10,700,appeare not climbed out of ground effect. 1F.
8. XXX	53, PPL, ASEL, IR, 366 TT, 125 MM, 21/41 act/sim IFR.	XXX ~30 nm, day	**Maintenance**, Left Aileron separated, missing hinge bolt, maintenance error, successful CAPS deployment. NF.
9. XXX	~70, PPL 1950, ASEL, NIR, 1880 TT, 76 MM.	XXX 130 nm, day.	**VFR-IMC,** CFIT in heavy fog 80 nm east of destination, at 6,450 MSL. 1F.
10. XXX	18 mos flying, PPL, ASEL, NIR, 215 TT, 12 MM.	XXX 100 nm.	**VFR-IMC**, CFIT at night, winter, full moon on snow covered ground, with blowing or precipitating snow. 2F.
11. XXX	PPL 8/00, IR. (1.5 hrs of IFR PIC), 460 TT, 360 dual.	XXX	**Approach-CFIT**, 1200 bkn, 4 nm, temp/DP spread 1 degree, turned off final approach course at San Jose. 1F.

Categories Summary: 4 VFR-IMCs; 2 or 3 Approach CFITs; 1 Maintenance; 1 Landing L/C; 1 Maneuvering; 1 Takeoff High Density Altitude; 0 – 1 Mechanical.

Appendix C: Sample Data Summary

DATA SUMMARY

Accident: Sierra Vista April 29, 2003

Location City, State	Sierra Vista AZ	NTSB Accid. No.	LAX 01 FA 145
Accident Date	April 10, 2001	Number on Board	3
N-Number	N 116CD	Injuries / Fatalities	0/3

Pilot Background	**Pilot 1 Douglas Koehler**	**Pilot 2**
Age / Years Flying		
Occupation/ EAA, AOPA		
License, Ratings	PPL, ASEL, NIR, Third class medical.	
Total / 90-day / MM Time	1,450 TT / ? / 116 MM as of 2/6/01.	
Init. Train: org, perf, date		
Recur. Train: org., dates		
IFR Hours actual/sim	Wings Aloft, recovery from VFR in IMC	
IFR PIC Actual		
IFR train in SR or other	Wings Aloft, instrument flying	
Other (Military,etc.)	familiarization.	

Aircraft Equipage: Model: SR 20. SN 1017. C Option.
Stormscope Lightning: N/A; Skywatch Traffic: N/A; Weather Data Link: No ; PFD: No
MFD: ARNAV; Ice protection equipment: No; Autopilot: S-TEC 55. Note: Not know if terrain feature turned on by pilot.

Mission
Type and purpose of flight: Part 91, day/night VFR. Returning from visiting relatives in Tucson AZ to home in Wisconsin so one passenger can receive award, two passengers.
Month; Time of day; day/night conditions: April, Tuesday, 1850 accident, sunset 1853.
Planned distance and duration: TUS (2641 MSL) to Alexander E80 (5191 MSL). 310 nm, approx. 2.25 hours.
Actual distance and duration: 52 nm, 20 minutes.
Altitudes MSL & AGL over flight: TO at 2641, crash at 5,200.
VMC/IMC and Flight plan type (if any): IMC, but pilot NIR and no flight plan.
Terrain over route: Mountainous.
Other factors (urgency, human factors from other activities): Urgency, possible passenger pressure to get home to receive award. Possible blood alcohol, takeoff at dinner time.

Weather Conditions and Information
Actual weather conditions: low clouds, mountain obscuration, gusty winds, freezing precipitation.
Weather information known to pilot: Only record of briefing 9 hours prior to flight.

Accident Type and Location (Immediate pre-accident and accident site information). CFIT or L/C, VFR into IMC, plus icing, gusty winds, turbulence. Freezing level at about 5,200 ft.
150 feet below mountain ridge, 5,200 MSL, 30 degree slope, single accident scar 50 ft radius.

Fact Issues:
Aware location and severity of hazardous weather: Unknown, because no record of weather briefing since 0926 and printed weather information in airplane issued at 0530.
Trained to interpret weather and make wx decisions: Unknown.
Pilot experienced in weather/terrain situation: Pilot from flatland in Wisconsin, different from mtns.
Equipment and maintenance problems: No evidence.
Pilot disorientation: Possible.
Weather impaired performance / control / upset: Possible icing.
ATC assistance to pilot: None.
Navigation/Approach type/experience: Not relevant.

Appendix D: Sample Event Sequence and HFACS Summary

EVENT SEQUENCE and HFACS Category
Accident: Sierra Vista, 4/10/01, SR 20, N116CD

April 29, 2003

Time	Event	HFACS Category
Feb 2, 2000	SR 20 delivered to Douglas Koehler, pilot of the accident airplane. SR 20 C option. 4 days of Wings Aloft training. No other CDC data available on pilot.	
	Pilot not instrument rated. From Wisconsin, visiting relatives in Tuscon, returning home.	Organizational Influences, Resource Management, manning requirements. – long cross country trips in mountainous areas without instrument license. We have no information on Oversight, in the form of continuing education, or the use of any risk management decision aid.
April 10, 2001, Tuesday.	Passenger needed to return to Wisconsin to receive award.	Unsafe Supervision, planned inappropriate operation, flight without instrument license. Preconditions for unsafe acts, Adverse Mental Status, self-imposed pressure, overconfident, focused on destination instead of overall weather situation, possible perceived pressure from passenger to return for award.
0535	TAF for ABQ issued. For 1800 – 2300, wind 270 at 20 gust 30, vis greater than 6, ceilings broken 7,000, showers in vicinity.	
0709	Pilot gets first DUAT briefing.	

Time	Event	HFACS Category
0926	Pilot gets second DUAT briefing. No record of FSS briefing. FA for AZ, south and east of TUS, chance of broken 11,000, tops FL220, scattered light rain showers, with conditions slowly improving. (PCF: good weather).	Substandard Practices or Operator, CRM, Pilot did not consult with FSS briefer at any time, despite not being based in the area.
1245	AIRMET Zulu, valid to 1900, occasional moderate rime/mixed icing in clouds and precipitation below 16,000, included departure and accident areas.	Substandard Practices or Operator, CRM, flight in potential icing conditions in mountains without ice protection.
1422	AIRMET Sierra, areas of mountain obscuration in clouds and precipitation, valid to 1900, included departure and accident areas.	
1525	AIRMET Tango, moderate turbulence, valid until 1900, included departure, destination and accident areas.	
1622	TAF for TUS issued, valid from 1700 on April 10 to 1700 on April 11. Wind 270 at 14 gust 24, visibility greater than 6, broken at 6,000, temporary between 1700 and 1900, light rain showers, small hail, cumulonimbus broken at 3,500. No indication pilot obtained TAF prior to departing since last DUATS briefing was at 0926.	
1655	Sierra Vista Weather Report (last one prior to accident): wind 250 at 24 gusting to 30, visibility 10 sm, showers in the vicinity, 5000 feet AGL scattered, 6000 scattered, Temp 8 C, DP –4C, 29.92. Peak wind 260 at 34 knots, 1601 Showers west to northeast and south	
1700	NWS weather. Closely packed isobars over AZ and NM, northwest southeart. Westerly winds over AZ 20 – 25 knots. Temp/dewpoint charts show nearly saturated at TUS, ABQ, and Flagstaff.	
1704	PIREP, B-727 at 2,700 MSL over TUS, low level wind shear +- 10 kts.	
1710	PIREP, MD80 at 11,000 MSL 12 nm on 090 bearing from TUS, light to moderate clear ice.	

Time	Event	HFACS Category
1755	Weather observation at TUS. 7,500 broken, 10 sm, 29.99, 11/5 C, 10/g17 kts from 280.	
1800, 1900	GOES visible and infrared, no useful data after 1830 due to darkness. Band of clouds across I-10 corridor east of Tucson from Rincon Peak north of I-10 to Whetsone mountains.	
1819	Pilot requests VFR departure clearance, for 3,800 ft, 100 degrees, destination Alexander Airport (E80), in Belen NM, 30 nm south of Albuquerque.	
1830	**No record of preflight weather briefing subsequent to 0926, therefore, no record that pilot was aware of any of the weather reports, AIRMETS, TAFS, PIREPs, etc. listed above from 1245 until departure, and weather in TUS still appears good.**	Substandard Practices of Operator, CRM, departs without weather update, no flight plan to activate search and rescue.
1830 lcl MST	**Aircraft departs** Tucson International Airport, destination E80. Belen NM, Alexander Airport, 5,191 MSL, lighted, 6,600 ft paved runway, about 300 nm Northeast of TUS. Pilot cleared for takeoff on runway 29R, makes right downwind departure.	
1843	ATC terminated radar services. At 1833, ATC turned pilot on course of 120. At 1835, turned pilot to 030 (to avoid the Davis-Montham AFB approach). At 1836, ATC approved pilot to turn "on course". No radar tracks after 1838.	Decision Error, pilot does not use flight following, underestimated risk of flight, failure to recognize severe weather conditions.
1845	All three AIRMETs issued earlier were updated, and made valid to 0100Z on April 11, these included areas surrounding arrival and destination areas.	
1846, 1851, 1856	Review of radar data, precipitation reflectivity in accident area increased during these observations, but no significant returns at accident site.	
1850	Closest weather reporting, Sierra Vista airport 4719 MSL, 11 nm south, southeast of accident site.	

Time	Event	HFACS Category
1850	No record of in-flight weather update. Printed weather information from Tucson to Wisconsin was found in wreckage, appeared incomplete, but more may have been burned. Included TAF for ABQ issued at 0535 on April 10 (PCF: this is consistent with no preflight weather briefing after 0926).	Substandard Practices of Operator, CRM, no current weather preflight, no weather update in flight, no flight following in adverse weather conditions.
	Witness (local deputy Sheriff who is a pilot) reports weather at time of accident, from his home 2 miles from base of accident mountain: “terrible”, with icing, sleet, know, rain, and wind, could not see bases of mountains from his home, low clouds obscuring higher terrain, gusting winds, freezing precipitation.	Decision Error. Continued flight in to multiple weather hazards.
1850	**Impact** mountainous terrain on side of ridgeline at 5,200 MSL, 150 feet below ridgeline in Whetstone Mountains, 52 nm SE of Tucson, 11 nm northwest of Sierra Vista. Witnesses: low clouds (IMC conditions) obscuring higher terrain, gusting winds, freezing precipitation.	Unsafe Acts, Decision Error, disregard for severity of weather.
1853	Sunset, end of civil twilight at 1918, moon 33 degrees below horizon.	
1855	Tucson weather observation (2641 MSL), 34 nm Northwest of accident site: Wind 280 at 10 gusting to 17, visibility 10, broken at 7,500 agl, temp 11 C, DP –5 C, 29.99. Rain and snow showers in distant NE to east, moving east. 1555, 1655, 1755 and 1855 observations from TUS and Davis Montham AFB, 6 nm NE of TUS, all had observations of snow showers over mountains, NW through SE, moving east.	Unsafe Acts, Decision Error, disregard for severity of weather. Violations, intentional VFR flight into IMC, failed to obtain current weather briefing. Violations, exceptional, continued VFR into IMC.
April 14	Wreckage in a single ground disturbance, within 50 ft radius, on 30-degree slope, burned, destroyed, no avionics or instrument readings available. ARNAV database found to display terrain elevations accurately. 3 fatalities. CAPS not deployed. Pathology test: Ethanol detected, but could have been from post-mortem production. No drugs.	

Appendix E: Sample Root Cause and HFACS Analysis

Root Cause and HFACS Analysis: Sierra Vista

April 29, 2003

Key Fact Summary:

- Pilot: PPL, ASEL, NIR. 1450 TT, 116+ MM, based in flatland Wisconsin. No evidence of mountain flying training or previous experience.
- Aircraft: SR 20, no wx DL, GPS moving map, ARNAV MFD w/ Terrain Data, no anti ice.
- Environment: Flying in mountains in AZ, NM, at freezing level, gusty, mountain obscuration, turbulence, rain, snow, sleet.
- Duration: Planned 2.25 hours, 310 nm. Actual 20 minutes, 52 nm.
- Urgency: Likely high: Evidence: passenger needed to be home to receive an award; departed at 6:30 PM with nightfall at 6:53, through the mountains in bad weather.

Inference - Evidence Summary

Inference	Evidence
Pilot may not be experienced in mountain flying.	Based in Wisconsin, visiting relatives in Tucson. Narrative statement.
Pilot used poor judgment in leaving at dusk.	Pilot under pressure to leave that day. Passenger needed to be back home to receive an award.
Pilot may be uncomfortable with large airports and ATC.	Destination is Alexander, rather then ABQ, 30 nm to north. Pilot does not request flight following.
Pilot is not very concerned with the weather, and not aware of the risk involved.	Initial DUATS briefings show good weather and in Tucson, weather remains until flight time. No record of updated preflight weather in the 9 hours prior to the flight, old weather printout in airplane, no EFAS weather request.
Pilot likely planned to fly east along the Interstate to Deming (the low altitude route), then north up the valley to Belen, but he is forced to the south of this course by bad weather. He is trying to maintain ground contact.	After flying a few miles on a heading of 100, ATC instructs to fly 030, then clears “on-course” heading.
Weather at accident site very bad, icing, gusty, turbulent, mountain obscuration, rain, snow, sleet.	Sheriff-pilot witness from 2 miles away and weather observation at Sierra Vista Airport.
Pilot likely flying on autopilot in the clouds or other low visibility conditions, and probably in control when he struck the ridge.	Airplane has autopilot, impacts level in CFIT mode of impact because wreckage scar is consistent with forward flight at time of impact.

Inference Description of Flight.

- Weather briefing very early, 0709 and 0926, decides not to go at that time, based on reports of good weather.

- Pilot does not update weather during the day because weather in Tucson is good.

- Immediate flight preparation one hour before sunset at TUS. TUS weather is 7500 broken, 10 sm, 11 C / 5C, 10 gusting to 17 from 280. Good VFR. Pilot has no information on TAF, AIRMETS or PIREPS, or current conditions in the mountains near his route, all of which contained information on bad weather.

- Pilot attempts to follow the highway east toward Deming, but is forced to the south by IMC conditions.

- Because he is not instrument rated, and because there ice in the clouds, he attempts to stay below the clouds and the freezing level (5,200 MSL at accident site) and maintain visual contact with the ground.

- Pilot's terrain warning on the ARNAV MFD ICDS 2000, if it has been selected on by the pilot, shows red ahead in the vertical cross section view with terrain warning. However this is not a plan view TAWS system, and he ignores the warning.

- Pilot is in and out of clouds that obscure the mountains, in gusty conditions, with rain, sleet, snow, hail or other precipitation. He is trying to go around a ridge, that has lower terrain to each side.

- Pilot impacts a 30-degree slope 150 feet from the ridgeline, probably trying to out-climb the terrain at the last instant when he sees the terrain ahead. He is probably in control, based on the 50 foot ground scar and the sloping terrain, and the fact he has as wing-leveling autopilot which would likely have been used by a VFR pilot to maintain control in these conditions.

Root Cause Analysis

Note: Focus on the causes leading to the potential TAA-specific interventions (ignore systemic national airspace system causes, such as faulty weather forecasts, that have been addressed in previous Safer Skies JSAT/JSIT process.

This is generally a classic VFR into IMC case with a standard Weather RCA applicable.

RCA Causes/Effects	RCA Interventions Specific to TAAs.
1.0 Aircraft strikes ground at high speed resulting in fatalities.	
1.1 BC Airplane had inadequate performance to out-climb downdrafts. OR	
1.2 BC CFIT due to pilot inability to navigate clear of terrain that he could not see in clouds or other low visibility conditions. May have been a visual illusion with the cloud top on the mountain creating a false ridge line. OR	
1.3 BC Pilot loses control of the airplane in IMC or turbulence.	
2.0 BC Pilot initiated and then continued flight on planned route/altitude into a weather hazard area caused by IMC, Icing, and Turbulence, at dusk and night, in mountainous terrain	
2.1 BC He was unable to oppose pressure to undertake flight at that time. AND/OR	
2.2. BC Pilot underestimated probability of IMC, icing, and turbulence on route of flight.	
2.2.1 BC of good weather forecast in early morning DUATS briefing and good weather in TUS during the day. AND	
2.2.2 BC Inadequate receipt of pre-flight and in flight briefing information on weather hazards. AND	

2.2.3 BC Inadequate pilot knowledge, skill and judgment in making weather risk assessments and making flight plans to address possible adverse weather.	Note: More capable airplane requires more judgment. For bizjet type ratings, FlightSafety training is a fixed duration. For CDC, no training requirement, but not get certificate, usually not get insurance, unless highly qualified, some not even require checkout. Matrix of airplane complexity and capability vs pilot qualifications, determines training requirements. More complexity, takes longer to spin up after not flying for a few days. But some new technology, that builds on VFR skills, requires less currency for proficiency. It depends on the qualities of the technology. Use of velocity vectors and boxes and synthetic vision terrain forward display. Have a flash card with all system configurations settings on it, plus routes, to go from one airplane to another. Teach pilots how to set up the airplane, and check that it is set up the same way.
AND 2.2.4. Pilot was lulled into believing the airplane and the avionics would permit safe flight in conditions that otherwise would have caused him to defer the flight.	TAA systems may increase probability of undertaking a flight in circumstances pilot would not otherwise fly in, without training on the limitations of the pilot-aircraft combination. Risk management training may need to be specific to TAA systems. Need integration of basics (review of sectional chart and MEFs before takeoff) with TAA, TAA can't stand alone. Emphasis on limitations of avionics – what they won't do. Early generation terrain warning (early ARNAV) does not have all information of Sectional; while it provides a terrain warning based on airplane altitude and terrain, it does not provide information the Sectional does, so pilots need to integrate use of the Sectional with the MFD with its warning. As avionics evolve, training must address each stage in the development, limitations and proper use of each generation of MFDs. Manufacturers must evolve their training to upgrades in the avionics. Pilots must get training in upgraded avionics they purchase (even software upgrades). Avionics manufacturers must provide pilots with limitation and proper use information for

	upgrades. Pilots must be trained to configure their systems properly for themselves in general, and for the terrain and weather situation of the particular flight. Mis-selection of airplane. Buying a computer with an airplane wrapped around it. Fallen away pilots, get back in, not computer savvy. Standardization. Even if the avionics are the same, multi-feature avionics (Sandell EFIS, Garmin, ARNAV, Avidyne) can be set up in a near infinite combination of configurations. How does training system know how much to show pilot, to avoid overwhelming pilot with information, and because there are so many combinations possible. Start formal training system for core functionality, then expand to options by pilot, with a self-training system to guide for pilots – possibly using self-guided study plus other flight instructors, PC training for part task training. Updated interactive Internet training for self-training, scenario based ancillary initial for all optional ways the avionics can be configured, and recurrent training. Individual responsibility through training to address non-standardization.
BC Once en route and he could see weather deteriorating, pilot did not change planned route/altitude in time to maintain safe separation from weather hazard area.	
3.1 BC Pilot underestimated risk of failure to maintain safe separation from weather hazard area caused by IMC, Icing, and Turbulence. OR	
3.2 BC Pilot overestimated his airplanes ability to out climb down drafts in mountains.	
Pilot struck the ridge.	
4.1 BC Pilot was operating in IMC but without the terrain protection of the IFR system.	
4.1.1 BC Pilot not instrument rated. AND	Note: of 11 accidents, all four fatal accidents with NIRs were VFR/IMC accidents.

	Provide guidance to pilots on when should have IR based on use of aircraft. Explain new IMC escape option with CAPS, e.g., climb and deploy. Cirrus Pilot Proficiency Program teaches VFR pilot how to get out using autopilot, heading mode to exit. Training to use but not abuse each of the systems, e.g., auto pilot. Judgment and risk assessment training is more necessary for TAAs because technology provides more information that needs to be analyzed, similar to proper use of weather radar, to make judgment on turning around. Does CAPS provide false sense of security for VFR pilot in MVFR/IMC; if I run out of options, can always save myself? CAPS provides more utility in going over mountains, may increase risk of off airport landings in mountains. But every new technology in aviation has always had the effect of increasing the likelihood of use of the airplane in circumstances that would formerly have led to not flying. SAGA: Technology, training, and decision making. FITS is the Part 91 element of SAGA. Insurance underwriters will put restrictions on TT, MM, plus completed CDC course. What are the analogies to the introduction of VORs, regarding encouraging more operations?
4.2 BC Pilot did not have avionics, training, and experience sufficient to navigate around terrain in IMC without IFR system protection. AND	
4.3 BC Airplane did not have performance and anti ice systems to deal with icing conditions, especially in turbulent and downdraft conditions.	

HFACS Analysis

HFACS Categories	HFACS Interventions specific to TAA
Organizational Influences, Resource Management, manning requirements, long cross country trips in mountainous areas without instrument license.	Judgment training regarding deciding whether a pilot needs and IR, based on his intended use of the airplane. Change capability to accommodate intended missions. Explicit matching of the pilot capability and mission, including need to meet a schedule, in the training. Even with no teeth, enlightened self interest. Teeth, tell their wives about the stats on NIR in IMC. Insurance industry: Stick of withhold insurance if not meet minimum training, and carrot of reduced premium for doing Flight Safety type training, including judgment training. Environment-specific training differences between where airplane is based and where route is, for mountains, over-water, high density altitude, low vis VMC, flat white/white out winter training; use of automation to address this. E.g., density altitude readout. Embed the TAA information in the existing mountain courses. Embed these environment specific elements in the TAA course, initial for pilots who live in mountain states. MFD tell pilot you can't go based on alt, temp, rwy length, assume gross weight and no wind.
Unsafe Supervision, planned inappropriate operation, flight without instrument license.	See above.
Preconditions for unsafe acts, Adverse Mental Status, self-imposed pressure, overconfident, focused on destination instead of overall weather situation, possible perceived pressure from passenger to return for award.	Misperception of aircraft capabilities compensating for lack of pilot capabilities, and not understanding aircraft limitations and limitations in avionics. How does FOM need to be modified for TAAs, including? Leading to incorrect risk assessment. I know computers, never hurt me, can figure it out, understand the difference between an airplane with lots of computers and a PC on your desk.
Substandard Practices or Operator, CRM, Pilot did not consult with FSS briefer at any time, despite not being based in the area.	Possibly pilot didn't seek FSS help because of capability of airplane. Training needs to explain still need to consult with briefer, especially in unfamiliar areas.

	Develop habit patterns and follow them and air discipline, and a sameness to every flight. In a non-TAA, lack of standardization on flight procedures can be tolerated, but in a complex TAA, non-standardization in flight procedures leads to more errors.
Substandard Practices or Operator, CRM, flight in potential icing conditions in mountains without ice protection.	
Substandard Practices of Operator, CRM, departs without weather update, no flight plan to activate search and rescue.	Train pilots in what things necessary in non-TAAs, TAA capabilities to not replace.
Decision Error, pilot does not use flight following, underestimated risk of flight, failure to recognize severe weather conditions.	Same. Failing to use resource available – flight following, because thinking TAA now replaces this. For TAAs with more capable avionics, may not need to retain old methods. Trained to adopt flight procedures appropriate to specific TAA.
Substandard Practices of Operator, CRM, no current weather preflight, no weather update in flight, no flight following in adverse weather conditions.	OEC Over Estimated Capability of TAA.
Decision Error. Continued flight in to multiple weather hazards.	OEC Failure to use airplane to save himself. Use of autopilot to turn around, use of MFD to alert to high terrain, or CAPS, climb above. Training on ways to use TAA capabilities to save self from mistakes.
Unsafe Acts, Decision Error, disregard for severity of weather.	OEC
Violations, exceptional, intentional VFR flight into IMC, failed to obtain current weather briefing.	OEC
Violations, exceptional, continued VFR into IMC.	OEC

TAA-Specific Analysis

<u>Potential Aircraft Differences: between TAAs (e.g. Cirrus SR-20/22 and Lancair 350/450) and typical lower-performance single engine airplanes (e.g., Cessna 172 </u>or Piper Warrior), and between similar higher-performance airplanes (e.g., Mooney or Bonanza).	
Combined speed and range, additional comfort and visibility, advanced navigation and autopilot and weather detection avionics, that together result in longer trips of several hundred miles, often involving transit across multiple weather systems, multiple terrain types, multiple climactic zones, different airport types. Probably Major impact.	Note: a Bonanza with a new interior and new avionics is very similar. Training on cross country scenarios. More people on the airplane, more pressure to go and to get there on time. More emphasis on risk assessment. More use for transportation need more ability to determine when not to.
Combined safety systems, e.g., Cirrus Airplane Parachute System (CAPS), autopilot, weather, terrain and traffic warnings, EFIS, FADEC, etc. possibly misleading some pilots to discount the importance of their own competence and believe that the airplane can take care of them in all situations. Probably Medium impact.	Definition of OEC. This accident.
Higher speed, when VFR in MVMC shortens time to decide how to avoid IMC and execute and escape maneuver before reaching IMC, by 30% compared to C-172. Probably smallest impact.	This accident. Training on the speed effect, less time before get to the hazard. Harder to run scud at 180 kts than 120 kts around big rocks. Behind the airplane, learn to fly the physical airplane, and makes dealing with the mental airplane harder because you have to make decisions faster. Training to increase the cycle time of decision making. Simulate scud running on a simulator and time survival.
<u>Potential Pilot Differences: between typical TAA pilots (e.g., Cirrus SR-20/22or Lancair 350/450) pilots</u> and C-172, Warrior, Mooney, and Bonanza pilots:	
Lower number of total years actively involved in aviation (flying, reading aviation magazines, talking and thinking about flying).	
Lower total flying time.	What is average hours of CDC and Lancair customers? Of the 10 CDC (non professional pilots): 0 – 500. 6 500 – 1000. 1

	See AOPA ASF books on hours of pilots in Mooneys, etc. Get COPA data without names. COPA to collect data on pilot usage and other information. Get info on CPPP from Mike.
Lower flying time in lower performance aircraft and less learning lessons “by osmosis” that are important, but not contained in formal training programs, specifically about their limitations, the limitations of their aircraft, and the power and unpredictability of the weather.	How many transition from low performance airplanes?
Lower percentage IFR rated pilots compared to the pilots of Bonanzas, Mooneys, etc.	Look in ASF book. COPA stats.
Less interest in the physics, engineering, and technology that underlies aircraft operation; interested solely in the transportation and life style benefits of flying.	Training system needs to level this out, compensate to for non-technical people. Similar to Bonanza Society, but maybe more techno geeks.
Less stick and rudder capability because of less time in light aircraft in take-off and landing situations and more use of autopilot en route (including not having to make heading changes for wind correction), leading to more landing incidents, prop strikes, etc. in gusts or cross wind conditions.	Get AirShares Elite, Cirrrus, and COPA data.
Less fundamental competence in the individual compared to the capabilities of the airplane. Less mental ability to operate sophisticated avionics and operate in the IFR system, keeping the 4-D picture in mind while controlling the airplane and its systems, and less psychological strength and emotional control to handle abnormal and emergency situations without panicking.	Get AirShares Elite, Cirrrus, and COPA data.
Less initiative and discipline to keep current, either VFR or IFR, through regular, frequent practice sessions. Pilots who are arrogant and overestimate their abilities, or do not understand the ½ life of flying capabilities, especially IFR control and procedures, and most especially the ability to deal with abnormal and emergency situations, are accident-prone. Currency means more than meeting the FAA minimum requirements; it is	

the real ability to continue to be able to use the airplane and the IFR system, based on practice and use of check pilots and pass/fail criteria.	
An arrogant attitude of individuals with more money than aviation capability. (Warbirds as said to have a similar problem.)	Some of this, CF non-TAAs? Bonanzas.
Relatively inexpensive airplane for its sophistication and capability, that is affordable by persons of lower socio-economic status, which in the free market US economy, generally indicates they are of lower-capability in terms of intellect, initiative, willingness to work for what they want, ability to control their emotions, etc.	Not true for initial owners.

Potential Interventions:	
Create an integrated operational system safety approach to the problem of TAA safety, including aircraft, FAA procedures, pilot training, safety systems, voluntary recurrence actions by contract rather than by regulation, etc.	FITS is a subset of SAGA.
1. Training improvements:	
Improved initial and recurrent training syllabi, with corresponding instruction guidance, including line oriented flight training (LOFT) and simulator-based recurrent abnormal situation training	"Scenario based", in place of LOFT like and simulator based.
Use of Weather Decision Making Flight Operations Manual.	Yes.
New TAA avionics training and testing syllabus, including GPS approaches, coupled autopilot approaches, use of PFD and MFD, and weather graphics, etc.	Yes.
Enable the pilot-owners to match the missions they intend to fly and the environment in which they will operate to their overall capabilities as determined by their initial and recurrent training and the equipment options selected for the airplane. For example, if the mission is frequent travel for business purposes over hundreds of miles, and the environment is areas of the US with IMC and severe weather and terrain, including in the winter, then the pilot must be IFR rated and current and the airplane should have the anti-ice system and weather data link. Conversely, if the pilot has decided not to get an IFR rating and not to equip the airplane with weather avoidance and tolerance systems, then he must cut back the mission and environment, to, for example, short trips, when the schedule if flexible, and less flying in winter. For pilots who live in mild climates and fly exclusively in those climates, there may not be a need for an IFR rating, such as Florida, Texas, California, where many GA pilots are located. Pilots must understand the limitations on TAA operations when the pilots do not have IFR ratings, or weather avoidance systems (e.g., Stormscope or weather data link), and weather tolerance systems (e.g., anti ice systems).	Yes. VFR scenarios vs IFR scenarios will show limitations of VFR only pilots.

Use of owner pilot shared ownership programs (OPSOPs) to require, by contract, enhanced training and currency requirements.	Yes.
Model-Specific Pilot Safety Seminars by manufacturers.	Yes. COPA.
Generally enhanced flight instruction, improved transition training programs.	Yes, FITS.
Ab initio private-instrument training (use company flying clubs for pilot programs).	Yes, FITS.
Flight instructor training that is aircraft and mission specific.	Yes, FITS.
2. Airplane Technology improvements:	
Terrain awareness and warning system (TAWS) unit	Yes or maybe helped in this accident.
Primary Flight Display (PFD)	Not in this accident.
Flight Data Recorder	Yes, would have helped. Recommendation, NTSB request analysis of any avionics that store FDC info. In OPSOP situations, manager review may deter the inner knucklehead.
Weather data link	Yes.

3. Pilot Qualifications:	
First-owner requirement for successful completion of training/testing program.	Some insurance is doing this.
Incentives and encouragement for IFR rating for pilots whose mission indicates the need for this rating, based on purpose of trips, distances, areas of the country, etc.	Yes. Nelson will tell me what is being done by Global.
Note on Currency: Persons who get an IFR rating, especially if they have little VFR experience, will be unsafe unless they are current, more unsafe than VFR pilots who limit themselves to VMC. Currency costs time and money. Owner-pilot shared ownership programs (OPSOPs) could require currency. Pilot associations could encourage currency. Insurance companies could require currency. This is currency beyond the FAA minimum, probably including simulator abnormal situation training, including weather, and testing, with a pass criteria for the training, not just completion.	Realistic IFR training, not just IFR maneuvers, but pilot able to fly in IFR system in IMC with TAA systems, based on scenario-based training.

Appendix F: HFACS Classifications

SUMMARY OF DECISION ERROR ANALYSES WITH REGARD TO HFACS CLASSIFICATION

ORGANIZATIONAL INFLUENCES

Resource Management

This category refers to the management, allocation, and maintenance of organizational resources. For example, how does the company mange its pilots, staff, and maintenance personnel with regard to selection, background checks, training, and manning requirements. In addition, this category includes the manner in which the company manages its non-human resources. Issues such as cost cutting or lack of funding for proper equipment have adverse affects on operator performance and safety.

Organizational Climate

*In general, organizational climate is the prevailing atmosphere within the organization and can be broken down into three over-arching categories: Structure, policies and culture. Structure **-** refers to the "form and shape" of an organization as reflected in the chain-of-command, delegation of authority and responsibility, communication channels, and accountability for actions. Organizations with maladaptive structures will be more prone to accidents. Policies **-** refers to hiring, promotion, retention, raises, sick leave, drugs and alcohol, overtime, accident investigations, use of safety equipment, etc. When these policies are ill defined, adversarial, or conflicting, safety may be reduced. Culture **-** refers to unspoken or unofficial rules, values, attitudes, beliefs, and customs of an organization that affect performance and safety.*

Organizational Process

*This category refers to the formal process by which things get done in the organization. It has at least three components. Operations **-** refers to the characteristics or conditions of work that have been established by management. These characteristics included operational tempo, time pressures, production quotas, incentive systems, schedules, etc. Procedures **-** The official procedures as to how the job is to be done. Examples include performance standards, objectives, documentation, instructions about procedures, etc. Oversight **-** refers to management's monitoring and checking of resources, climate, and processes to ensure a safe and productive work environment. Issues here relate to organizational self-study, risk management, and the establishment and use of safety programs. All of these organizational factors, if inadequate, can negatively impact employee supervision, performance, and safety.*

UNSAFE SUPERVISION

Inadequate Supervision

The role of any supervisor is to provide the opportunity to succeed. To do this, the supervisor, no matter at what level of operation, must provide guidance, training opportunities, leadership, and motivation, as well as the proper role model to be emulated.

Planned Inappropriate Operations

Occasionally, the operational tempo and/or the scheduling of aircrew are such that individuals are put at unacceptable risk, crew rest is jeopardized, and ultimately performance is adversely affected. Such operations, though arguably unavoidable during emergencies, are unacceptable during normal operations.

Failed to Correct Problem

Failed to Correct a Known Problem, refers to those instances when deficiencies among individuals, equipment, training or other related safety areas are "known" to the supervisor, yet are allowed to continue unabated.

Supervisory Violation

Supervisory violations, on the other hand, are reserved for those instances when supervisors willfully disregard existing rules and regulations.

PRECONDITIONS FOR UNSAFE ACTS

SUBSTANDARD CONDITIONS OF OPERATOR

Adverse Mental States

The category of Adverse Mental States was created to account for those mental conditions that affect performance. Principal among these are the loss of situational awareness, task fixation, distraction, and mental fatigue due to sleep loss or other stressors. Also included in this category are personality traits and pernicious attitudes such as overconfidence, complacency, and misplaced motivation.

Adverse Physiological States

Adverse physiological states refer to those medical or physiological conditions that preclude safe operations. Particularly important to aviation are such conditions as visual illusions and spatial disorientation as described earlier, as well as physical fatigue, and the myriad of pharmacological and medical abnormalities known to affect performance.

Physical/Mental Limitations

This category refers to those instances when necessary visual or aural information is not available due to limitations inherent within the sensory system. For instance, in aviation, this most often includes not seeing other aircraft, power lines, or other obstacles due to the size or contrast of the object in the visual field. There may also be times when the individual's inherent aptitude, experience, and/or proficiency are incompatible with the characteristics or requirements of the task.

SUBSTANDARD PRACTICES OF OPERATOR

Crew Resource Mismanagement

Crew resource mismanagement was created to account for occurrences of poor coordination among personnel. Within the context of aviation, this includes coordination both within and between aircraft with air traffic control facilities and maintenance control, as well as with facility and other support personnel as necessary. But aircrew coordination does not stop with the aircrew in flight. It also includes coordination before and after the flight with the brief and debrief of the aircrew.

Personal Readiness

In aviation as in other professions, personal readiness failures occur when individuals fail to ensure that they are physically or mentally for duty. For instance, violations of crew rest requirements, bottle-to-brief rules, and self-medicating all will affect performance on the job and are particularly detrimental in the aircraft. This also includes those individuals that have not prepared mentally for the flight (e.g., students unprepared for the training flight).

UNSAFE ACTS OF OPERATORS

ERRORS

Errors are generally defined as mental or physical activities that fail to achieve their intended outcome. There are three basic error types - decision, skill-based, and perceptual.

Decision Errors

Decision errors represent intentional behavior that proceeds as intended, yet the plan proves inadequate or inappropriate for the situation. Often referred to as "honest mistakes," these unsafe acts represent the actions or inactions of individuals whose "hearts are in the right place," but they either did not have the appropriate knowledge or just simply chose poorly.

Skill-based Errors

Skill-based behavior within the context of aviation is best described as "stick-and-rudder" and other basic flight skills that occur without significant conscious thought. As a result, these skill-based actions are particularly vulnerable to failures of attention and/or memory.

Perceptual Error

Perceptual errors occur when sensory input is degraded or "unusual," as is the case with visual illusions and spatial disorientation or when aircrew simply misjudges the aircraft's altitude, attitude, or airspeed.

VIOLATIONS

By definition, errors occur within the rules and regulations espoused by an organization. In contrast, violations represent a willful disregard for the rules and regulations that govern safe flight and, fortunately, occur much less frequently since they often involve fatalities.

Routine

Routine violations tend to be habitual by nature and often tolerated by governing authority. These violations are typically referred to as 'bending the rules (e.g., driving 65 mph in 55 mph zone).

Exceptional

Exceptional violations appear as isolated departures from authority, not necessarily indicative of individual's typical behavior pattern nor condoned by management (e.g., driving 105 mph in 55 mph zone).

Appendix G: Interventions List and Description

TAA Safety Study
Interventions List

June 10, 2003

The following Interventions List is a compilation of the interventions developed by the TAA Safety Study Team at its April 29-30, 2003 meeting. At this meeting, 11 TAA accidents were analyzed, based upon Data Summaries, Event Sequences, and Root Cause Analysis documents prepared in advance of the meeting, and upon review of the NTSB factual files available to the Team.

Following this meeting, the interventions determined by team members were extracted from the general meeting notes and the Analysis documents for each of the accident cases. These interventions were identified to the cases from which they were extracted, grouped according to four main categories, and several sub-categories, and then duplicates were eliminated and similar interventions combined.

The table below lists an ID for each intervention to associate it with used to document the effectiveness and feasibility evaluation of the intervention by the Team members at the upcoming meeting on June 10, 2003. See the attached Intervention Evaluation Form. The Reference is the number that has been assigned to the principal accident(s) from which the intervention was extracted. See the attached Case Overview for the accident list with their numbers. Next, the table contains the category, sub-category, name, and description of the intervention. The categories and sub-categories are:

- Technology: Aircraft and avionics design, certification, and equipage.
    - Hazard Display
    - Automation Status Display

- Procedures: Flight operations, air traffic procedures, or flight services.
    - New TAA Opportunities

- Training: Pilot, instructor, and examiner.
    - Requirements
    - TAA Opportunities
    - TAA Limitations
    - Risk Management

- Others: Activities of other entities.
    - Accident Investigators
    - Instructors and Examiners
    - Insurers
    - Owner-Pilot organizations

Intervention List

		Technology
ID	**Ref.**	**Intervention Category: Subcategory: Name and Description**
A-1	1, 2, 4, 9, 10	**Technology: Hazard Display: Weather graphics display.** Weather information data linked to and displayed in the cockpit, including graphics updated as forecasts, observations, or diagnostics are updated, and would provide pilots with a warning of up-to-date weather hazard areas, well before entering the hazard area. Ceiling and Visibility information (national C&V and graphical METARS, icing, convection information needed).
A-2	1, 2, 7, 9, 10, 11	**Technology: Hazard Display: Terrain display and warning.** TAWS system, with a visual and audio warning of terrain, always turned on, clearly showing the pilot when heading toward high terrain.
A-3	2, 7	**Technology: Hazard Display: High-density altitude warning.** Avionics that have air data systems with temperature, encoders for altitude, and GPS data bases with at least airport altitude. At least provide density altitude figure. Could also have runway length and surrounding terrain altitude, could apply these against the airplane's performance charts and warn the pilot when a takeoff cannot be made safely because of high density altitude, or alternatively tell the pilot at what gross weight and wind conditions a takeoff could be safety accomplished.
A-4	4, 7	**Technology: Hazard Display: TAA system warnings of traditional pilot error – fuel exhaustion or mismanagement.** The computers, data bases, etc of TAA systems should be used to detect traditional pilot errors, and provide warnings and directions for resolving them. If the fuel tanks have been switched properly, if the fuel on board is adequate for the planned flight plus reserves. The systems could tell the pilot to switch tanks when one has fuel, the other doesn't, and the engine stops running, etc. Get pilot's attention with master warning/caution light in primary field of view.
A-5	5, 11	**Technology: Automation Status Display: Autopilot status/disconnect warning.** Provide a clear indication to the pilot whether autopilot is on or off, and both visual and aural warnings when it has been disconnected.
A-6	2, 9	**Technology: Automation Status Display: Pilot-specific avionics configuration setting.** Enable pilots to quickly and consistently set up their avionics in the way they desire as their "standard" configuration, similar to cars that enable a driver to define his seat and mirror positions and then recall and reset all of them with one button. This would "standardize" the same avionics configuration for the pilot, even between different rental airplanes, as long as they had the same avionics units.

		Procedures
ID	**Ref.**	**Intervention Category: Subcategory: Name and Description**
B-1	2, 4, 5, 7, 9	**Procedures: New TAA Opportunities: Develop TAA procedures that take advantage of TAA systems in normal operations.** TAA Procedures are the methods of competently (even if not completely) using the TAA systems to take advantage of the major safety opportunities provided by TAA systems. These are procedures not available to pilots of non-TAAs. These methods are utilized when the pilot has knowledge of the techniques for operating the equipment and can skillfully use the systems based on practice.
B-2	2, 4, 5, 8,10	**Procedures: New TAA Opportunities: Create new IMC escape procedure using TAA systems for rare normal and abnormal operations.** Create new "IMC escape" procedures for pilots with aircraft equipped with TAA systems, such as autopilots, MFDs, and parachutes. The primary IMC avoidance procedure is changing route or altitude before entering the IMC. If this fails, and IMC is inadvertently entered, the primary TAA-enabled escape maneuver uses the autopilot, monitored by the pilot, to avoid loss of airplane control, and uses the MFD for situational awareness in the turn to avoid any high terrain while exiting the IMC. The autopilot and MFD could also be used in a procedure to climb when a white out situation is encountered. The airframe parachute deployment procedure would be executed when the pilot determines he is not able to safely execute the above IMC escape maneuver, i.e., the pilot does not believe he has and can maintain certain aircraft control (perhaps because of a perceived instrument failure) or concludes he can not reliably avoid nearby high terrain by normal maneuvers and cannot fly to VFR conditions. In such cases the pilot would escape this situation by climbing to a specified AGL altitude and deploying the airframe parachute. The parachute escape procedure would be used only when the other procedures for avoiding inadvertent IMC and escaping from it fail.

		Training
ID	**Ref.**	**Intervention Category: Subcategory: Name and Description**
C-1	2, 4, 5, 7, 8, 9, 10, 11	**Training: Requirements: Realistic, scenario-based training.** TAA training, including computer simulation based training, should be built around realistic, cross-country GA flight scenarios, including abnormal situations, and typical accident scenarios (e.g., mountain terrain with IMC). These scenarios should be contained in the training syllabus, in written and computer-based training materials, and in flight simulations, such as the FITS program is developing. TAA training should include actual IMC, if possible.
C-2	2, 7, 9, 10	**Training: Requirements: Environment-specific training.** Include in the scenario based training program, probably in the simulator or on the web, sections on using TAA systems in flight environments that often result in accidents: e.g., mountainous areas (both terrain induced weather and high density altitude), winter conditions (flat white and white out conditions). Reference existing mountain flying and other related training resources. For pilots who are based in or near mountain areas, this should be covered in the initial "core" training; for those based in flat land areas, it could be part of the supplemental, pilot self-training materials.
C-3	2, 4, 5, 6, 7, 9, 10	**Training: Requirements: Apply SAGA principles.** Provide an application of "Technology-Training-Decision Making" principles of the FAA's SAGA, system safety approach in TAA training programs.
C-4	2, 3, 4, 5, 9, 10	**Training: Requirements: Recognize additional net training requirements for TAA pilots.** TAA training should indicate to pilots that "net" additional pilot training is required for TAA operations. This is because the pilot must still know all of the old technology procedures, and must also learn the new TAA opportunities, the procedures for maximizing these opportunities, and the technical and operational limitations of TAA systems, and judgment for using the new systems wisely.
C-5	2, 3, 4, 5, 7, 9	**Training: Requirements: Integrate flying "basics" with TAA-specific training.** TAA systems do not eliminate the need of pilots to know anything they needed to know to fly non-TAAs. Therefore, since pilots of TAAs must know all of the "old" information plus the "new" information, both should be integrated in the TAA training curriculum. For example, pilots still must have a good instrument scan, know how to get good weather briefings, and how to recover from unusual attitudes.
C-6	2, 3, 4, 5,	**Training: Requirements: Pilot performance requirements.** Training requirements should be based on the complexity and capability of the aircraft/avionics, noting that all technology that performs the same function is not equal – some requires more training than others for equal proficiency. Training should be completed to a tested performance standard using real-world scenarios.
C-7	2, 4, 7, 9, 10	**Training: Requirements: TAA pilots still need weather briefings.** TAA avionics, including lightning detectors and weather data link displays, do not completely replace weather briefings and in-flight advisories. No data link system contains all of the available weather information, and these briefings and advisories add value in interpreting the weather information, especially for new pilots and those inexperienced with flying in a new geographic area.

ID	Ref.	Intervention Category: Subcategory: Name and Description
C-8	2, 3, 4, 5	**Training: Requirements: TAA pilots need a disciplined approach to flying.** Having a standardized, disciplined approach to flying is even more important in a TAA than a non-TAA. This is because of the greater aircraft capabilities and the substantially greater number of available aircraft "configurations" that the pilot may select on his multi-function avionics. The pilot should be trained to determine the optimum configuration of TAA systems for him, and then set up the airplane that way every flight.
C-9	2, 4, 9	**Training: Requirements: Train to use all available resources.** TAAs do not completely replace any resources necessary for non-TAA operations. TAA pilots should continue to get en route weather information, get flight following services for quick assistance if conditions deteriorate and for search and rescue, to use sectional charts when MFDs are not also TAWSs.
C-10	2, 9	**Training: Requirements: Use of non-TAA information to supplement TAA capabilities.** Some TAA systems, of more limited capabilities, require supplementation with old systems, such as sectional charts.
C-11	2, 5, 9	**Training: TAA Opportunities: Train to fly the "mental airplane".** Understanding the avionics systems is sometimes termed flying the "mental airplane", and a subset of this is "knobology", i.e., knowing how to actually operate the avionics to get the desired function. This training enhances the pilot's understanding of how to actually get the maximum safety and utility benefits from the TAA systems and both existing and new TAA procedures. Together, this is the Technology-Procedures-Training (T-P-T) combination for increased safety. This training includes interpretation of lightning detectors, weather radar, weather graphics, TAWS systems, and traffic avoidance systems. Older pilots, who generally are not as proficient with computers as younger pilots, may need additional instruction to build proficiency in the use of computer-driven TAA systems. Scenario-based training should include the proper circumstances for using airframe parachutes, and setting up amended instrument approaches on their GPS navigators quickly and within their instrument scan. Pilots must be able to fly both autopilot-coupled and hand-flown instrument approaches.
C-12	2	**Training: TAA Opportunities: Supplemental self- training for TAA system upgrades.** Upgraded features of TAA systems, commonly occurring through software updates, require additional manufacturer information for pilots to train themselves in proper use and limitations.
C-13	2	**Training: TAA Opportunities; TAA system configuration training.** TAA training must include the method for the pilot to determine the proper configuration of the TAA systems for his method of processing information, his typical type of operation, and the specific mission at hand.
C-14	2, 7	**Training: TAA Opportunities: Core and Options Training.** The training program should provide instruction on the proper operation and limitations of the "core" configurations and capabilities of the TAA systems, and then provide guidance for the pilot on how he should self-train on the "optional" system configurations and capabilities using manufacturer guidance materials, stressing the pilot's responsibility for this additional self-training.

ID	Ref.	Intervention Category: Subcategory: Name and Description
C-15	2, 4, 9, 10	**Training: TAA Opportunities: Competence in use of all TAA systems.** TAA pilots should know how to use their systems – both to be able to take advantage of them for increased safety and to avoid reduced safety though misuse or increased workload. Training should include the use of all major TAA system capabilities. (This should include training in the use of color coding in both system status annunciators and strategic displays in weather data link displays.)
C-16	2, 4, 5, 7, 9, 10	**Training: TAA Opportunities: Train new IMC escape procedures using autopilot and parachute.** Provide training on new "IMC escape" option for pilots with aircraft equipped with a parachute. This procedure would generally provide that a pilot not capable of continuing the flight safely in IMC conditions, who believed he did not have and could maintain certain aircraft control, would execute an escape procedure involving a climb to a specified AGL altitude and a CAPS deployment. This could be integrated into the Pilot Proficiency Program training on inadvertent IMC encounters, and would be used if the primary escape maneuver is based on use of the autopilot for airplane control and the MFD for turning around and avoiding high terrain, failed for any reason. This escape procedure is used only when the basic procedure for avoiding inadvertent IMC – turning around before entering the IMC – fails for some reason. Having a plan to use the TAA systems in an emergency will also help to avoid panic.
C-17	2, 3, 4, 9	**Training: TAA Limitations: TAA judgment training.** TAA Judgment results from the pilot's understanding of the limitations of the technology and related procedures, his own limitations – and the combined overall capability of the pilot and the TAA -- especially when flying in unfamiliar situations.
C-18	2, 4, 9	**Training: TAA Limitations: Train to avoid over-estimating capabilities.** Specifically train pilots of the danger of over estimating the capabilities of TAA systems. Where a TAA system improves capability 10%, and the pilot may believe that it improves his capability 100%, safety is only preserved if the pilot operates at the 10% increased utility level. Also, pilots must understand that TAA systems do not allow them to be a less competent pilot and still take a given trip – in fact they must be more competent to fly safely at the maximum utility the TAAs can provide.
C-19	2, 4, 5, 9, 11	**Training: TAA Limitations: "How to Kill Yourself with TAA Avionics".** Training syllabi, in addition to providing information on limitations when discussing each element of the operation of TAA systems, should also provide a separate section on how deliberate pilot misuse of the systems can lead to catastrophe. This training would demonstrate total TAA limitations, including technical limitations (e.g., loss of GPS signal, inaccurate terrain data busses, inadequate airplane performance), pilot limitations (flying difficult procedures without adequate margin for error), lack of procedures that completely replace the IFR system, and the resulting vast reduction of safety from the entire IFR system if IMC flight is attempted by VFR pilots. Training must enable pilots to avoid overly confident estimates of their ability to complete difficult missions in the TAA.

ID	Ref.	Intervention Category: Subcategory: Name and Description
C-20	2, 4. 9, 10, 11	**Training: Risk Management: TAA Risk Management Training.** In addition to the generic weather and personal risk management training, TAA pilots should have additional risk management training on considerations associated with the TAA. These would include a clear understanding of the technical limitations of the avionics, and the operational limitations of the total TAA technology-procedures-training system, emphasizing the fact that TAA systems do not fully replace the redundant safety layers of the complete "IFR system", and the consequent fact that operating in IMC under VFR even with the TAA systems results in operational safety several orders of magnitude lower than an IFR operation (which the VFR-in-IMC accident statistics are reflecting, with an estimated 4-9s fatal accident rate, instead of the desired 7-9s rate, although better than an estimated 2-9s rate in non-TAAs). Guidance should be prepared on how TAA systems affect a pilot's personal minimums.
C-21	2, 3, 9	**Training: Risk Management: Proper Selection of Airplane for Pilot and Mission.** TAA risk assessment guidance should include how the pilot as aircraft owner should select the airplane based on his ability to properly operate sophisticated systems and high-capability, high-performance aircraft.
C-22	2, 4, 9	**Training: Risk Management: Guidance to Pilots on when Instrument Rating is Needed.** Manufacturers, instructors, and insurers should provide guidance to pilots on whether their mission profiles indicate the need for an instrument rating. This would include traveling with groups of people (some of whom may be under time pressure), and the percentage of flights used for transportation, as opposed to recreation. Training that includes both VFR and IFR scenarios for the same trip with marginal and potentially IMC weather conditions can assist in providing this guidance.
C-23	2, 4, 9, 10	**Training: Risk Management: Combined effects in faster TAAs.** Pilots must understand that the higher cruise speed, lower drag, and higher wing loading of some TAAs creates even more need for pilot competence because the physical airplane requires more attention at the same time the mental airplane requires more attention. At higher speeds, there is less time for the pilot to consider and avoid weather and terrain hazards from when they are detected to when they are encountered. Higher speeds also enable pilots to take longer trips, encountering more weather systems and terrain types on one trip than they would in less capable airplanes.
C-24	3, 4, 5, 6, 8, 10, 11	**Training: Risk Management: Lower pilot experience in high capability airplane.** Pilots with limited number of years in aviation and limited total time, cross country time, and instrument time, must be trained to recognize their limitations. They must also learn the importance of using caution in the missions they undertake or increasing their formal training to compensate for their lack of experience.
C-25	2, 7, 9	**Training: Risk Management: Older Pilots in computer-intensive airplanes.** Older pilots who are not as computer-capable as younger pilots should understand this additional risk factor, and get additional practice in the use of advanced TAA systems.

		Others
ID	**Ref.**	**Intervention Category: Subcategory: Name and Description**
D-1	All	**Others: Accident Investigators: NTSB extract flight data from avionics.** In all fatal accidents where any of the avionics store flight data (based on list of avionics with this capability kept by NTSB), avionics should be sent to manufacturer to extract the flight data for accident analysis.
D-2	All	**Others: Instructors-Examiners: Instructors must teach, and examiners must test in the use of TAA systems.** CFIs and examiners must be familiar with TAA systems installed in the airplane (current PTS requirement), must use them in instrument and other flight training, and must ensure that pilots of TAAs meet minimum proficient standards for their use through testing of maneuvers using the TAA systems, as well as without using the TAA systems. Possible methods of validating instructor qualification on navigators: free, on-line (possibly FAA or AOPA website) FITS, based on manufacturer-developed course, or commercial CD ROM courses and log book entry, or endorsement by an avionics or OEM approved instructor.
D-3	All	**Others: Insurers: Insurance incentives for minimum and advanced TAA training.** Insurance underwriting standards should be based on providing insurance only upon pilot meeting minimum TAA training requirements, and should provide premium reductions for superior training. This would involve not only participation in a training program, but also meeting specified proficiency criteria upon training course completion.
D-4	All	**Others: Owner-Pilot Organizations: Owner-pilot organization model-specific training and safety programs.** Type-specific owner and pilot associations should take an active safety role by keeping statistics on their members that would aid in targeting training and other safety data to them, and in conducting or facilitating training programs.
D-5	All	**Others: Shared-Ownership Organizations: Contractual additional training requirements.** Owner-pilot shared ownership programs should require pilots to pass more stringent initial training programs, enable flight training on actual trips, and require more than the minimum recurrent training and testing.
D-6	All	**Others: Accident Investigators. Avionics Record Button Pushes.** Modify avionics to record all button pushes on navigators, autopilots, etc.
D-7	All	**Others: Accident Investigators.** Cameras to record pilot actions and weather conditions. Put data chips in crash-survivable container.

Appendix H: Sample Individual Evaluation Form

TAA Safety Study: Intervention Evaluations (SAMPLE INDIVIDUAL)
1 = Low, 2= Medium, 3 = High
Rate Effectiveness; Rate Technical, Financial, Regulatory, and Operational Feasibility, and then Composite Feasibility
May 26, 2003

ID	Name	Effect-iveness	Tech. Feas.	Finan. Feas.	Reg. Feas.	Ops. Feas.	Comp. Feas.
A-1	Technology: Hazard Display: Weather graphics display.	3	2	2	2	3	2
A-2	Technology: Hazard Display: Terrain display and warning.	3	3	2	2	3	2
A-3	Technology: Hazard Display: High-density altitude warning.	3	3	3	2	3	3
A-4	Technology: Hazard Display: TAA system warnings of traditional pilot errors.	3	2	3	2	3	3
A-5	Technology: Automation Status Display: Autopilot status/disconnect warning.	3	3	3	3	3	3
A-6	Technology: Automation Status Display: Pilot-specific avionics configuration setting.	3	3	3	3	3	3
B-1	Procedures: New TAA Opportunities: Develop TAA procedures that take advantage of TAA systems in normal operations.	3	3	3	3	3	3
B-2	Procedures: New TAA Opportunities: Create new IMC escape procedure using TAA systems for rare normal and abnormal operations.	3	3	3	3	3	3
C-1	Training: Requirements: Realistic, scenario-based training.	3	3	3	3	3	3
C-2	Training: Requirements: Environment-specific training.	3	2	2	3	2	2
C-3	Training: Requirements: Apply SAGA principles.	3	3	3	3	3	3

C-4	Training: Requirements: Recognize additional net training requirements for TAA pilots.	3	3	3	3	3	3
C-5	Training: Requirements: Integrate flying “basics” with TAA-specific training.	3	3	3	3	3	3
C-6	Training: Requirements: Pilot performance requirements.	3	3	3	2	2	3
C-7	Training: Requirements: TAA pilots still need weather briefings.	3	3	3	3	3	3
C-8	Training: Requirements: TAA pilots need a disciplined approach to flying.	3	3	3	3	3	3
C-9	Training: Requirements: Train to use all available resources.	3	3	3	3	3	3
C-10	Training: Requirements: Use of non-TAA information to supplement TAA capabilities.	3	3	3	3	3	3
C-11	Training: TAA Opportunities: Train to fly the “mental airplane”.	3	3	3	3	2	3
C-12	Training: TAA Opportunities: Supplemental self- training for TAA system upgrades.	3	3	3	3	3	3
C-13	Training: TAA Opportunities; TAA system configuration training.	3	3	3	3	3	3
C-14	Training: TAA Opportunities: Core and Options Training.	3	3	3	3	3	3
C-15	Training: TAA Opportunities: Competence in use of all TAA systems.	3	3	3	3	3	3
C-16	Training: TAA Opportunities: Train new IMC escape procedures using autopilot and parachute.	3	3	3	3	3	3
C-17	Training: TAA Limitations: TAA judgment training.	3	3	3	3	3	3

C-18	Training: TAA Limitations: Train to avoid over-estimating capabilities.	3	3	3	3	3	3
C-19	Training: TAA Limitations: "How to Kill Yourself with TAA Avionics".	3	3	3	3	3	3
C-20	Training: Risk Management: TAA Risk Management Training.	3	3	2	3	3	3
C-21	Training: Risk Management: Proper Selection of Airplane for Pilot and Mission.	3	3	3	3	3	3
C-22	Training: Risk Management: Guidance to Pilots on when Instrument Rating is Needed.	3	3	3	3	3	3
C-23	Training: Risk Management: Combined effects in faster TAAs.	3	3	3	3	3	3
C-24	Training: Risk Management: Lower pilot experience in high capability airplane.	3	3	3	3	2	3
C-25	Training: Risk Management: Older Pilots in computer-intensive airplanes.	3	3	3	3	2	3
D-1	Others: Accident Investigators: NTSB extract flight data from avionics.	3	3	3	3	2	3
D-2	Others: Instructors-Examiners: Instructors must teach, and examiners must test in the use of TAA systems.	3	3	2	2	2	3
D-3	Others: Insurers: Insurance incentives for minimum and advanced TAA training.	3	3	3	3	3	3
D-4	Others: Owner-Pilot Organizations: Owner-pilot organization model-specific training and safety programs.	3	3	2	3	3	3
D-5	Others: Shared-Ownership Organizations: Contractual additional training requirements.	3	3	3	3	3	3

Appendix I: Team Evaluation Summary

TAA Safety Study: Team Intervention Evaluations Summary
1 = Low, 2= Medium, 3 = High

June 10, 2003

ID	Name	Effectiveness Degree of improvement in safe-utility Both or New/Retrofit	Tech. Feas. No risk Mod risk Hi risk Both or New/ Retro	Finan. Feas. % TAA pilots >75% 25-75% <25% Both or New/ Retro	Reg. Feas. No chg Policy chg Rule chg Both or New/ Retro	Ops. Feas. No chg Mod chg High chg Both or New/ Retro	Comp. Feas. Median of all Feasibility measures Both or New/ Retro
A-1	Technology: Hazard Display: Weather graphics display.	High -4 Med -4 Low -0	0 6 2	0 7 1	8 0 0	8 0 0	High New Low Retro
A-2	Technology: Hazard Display: Terrain display and warning.	8 0 0	8 0 0	0 7 1	8 0 0	8 0 0	High New Low Retro
A-3	Technology: Hazard Display: High-density altitude warning.	2 4 2	8 0 0	0 5 3	8 0 0	8 0 0	High New Low Retro
A-4	Technology: Hazard Display: TAA system warnings of traditional pilot errors.	8 0 0	8/0 0 0/8	8/0 0 0/8	8 0 0	8 0 0	High New Low Retro
A-5	Technology: Automation Status Display: Autopilot status/disconnect warning.	7 0 1	8 0 0	0 8 0	8 0 0	8 0 0	High New Low Retro
A-6	Technology: Automation Status Display: Pilot-specific avionics configuration setting.	2 4 2	8/0 0 0/8	8/0 0 0/8	0 8 0	8 0 0	High New Low Retro
B-1	Procedures: New TAA Opportunities: Develop TAA procedures that take advantage of TAA systems in normal operations.	See Note.	See Note	See Note	See Note	See Note	High New Low Retro
B-2	Procedures: New TAA Opportunities: Create new IMC escape procedure using TAA systems for rare normal and abnormal operations.	See Note.	See Note	See Note	See Note	See Note	High New Low Retro

C-1	Training: Requirements: Realistic, scenario-based training.	See Note	7 for all C items 0 0	0 7 See Note 0	7 for all C items 0 0	7 for all C items 0 0	High New Mod Retro
C-2	Training: Requirements: Environment-specific training.	See Note	7 for all C items 0 0	0 7 See Note 0	7 for all C items 0 0	7 for all C items 0 0	High New Mod Retro
C-3	Training: Requirements: Apply SAGA principles.	See Note	7 for all C items 0 0	0 7 See Note 0	7 for all C items 0 0	7 for all C items 0 0	High New Mod Retro
C-4	Training: Requirements: Recognize additional net training requirements for TAA pilots.	See Note	7 for all C items 0 0	0 7 See Note 0	7 for all C items 0 0	7 for all C items 0 0	High New Mod Retro
C-5	Training: Requirements: Integrate flying "basics" with TAA-specific training.	See Note	7 for all C items 0 0	0 7 See Note 0	7 for all C items 0 0	7 for all C items 0 0	High New Mod Retro
C-6	Training: Requirements: Pilot performance requirements.	See Note	7 for all C items 0 0	0 7 See Note 0	7 for all C items 0 0	7 for all C items 0 0	High New Mod Retro
C-7	Training: Requirements: TAA pilots still need weather briefings.	See Note	7 for all C items 0 0	0 7 See Note 0	7 for all C items 0 0	7 for all C items 0 0	High New Mod Retro
C-8	Training: Requirements: TAA pilots need a disciplined approach to flying.	See Note	7 for all C items 0 0	0 7 See Note 0	7 for all C items 0 0	7 for all C items 0 0	High New Mod Retro
C-9	Training: Requirements: Train to use all available resources.	See Note	7 for all C items 0 0	0 7 See Note 0	7 for all C items 0 0	7 for all C items 0 0	High New Mod Retro
C-10	Training: Requirements: Use of non-TAA information to supplement TAA capabilities.	See Note	7 for all C items 0 0	0 7 See Note 0	7 for all C items 0 0	7 for all C items 0 0	High New Mod Retro
C-11	Training: TAA Opportunities: Train to fly the "mental airplane".	See Note	7 for all C items 0 0	0 7 See Note 0	7 for all C items 0 0	7 for all C items 0 0	High New Mod Retro
C-12	Training: TAA Opportunities: Supplemental self- training for TAA system upgrades.	See Note	7 for all C items 0 0	0 7 See Note 0	7 for all C items 0 0	7 for all C items 0 0	High New Mod Retro
C-13	Training: TAA Opportunities; TAA system configuration training.	See Note	7 for all C items 0 0	0 7 See Note 0	7 for all C items 0 0	7 for all C items 0 0	High New Mod Retro

C-14	Training: TAA Opportunities: Core and Options Training.	See Note	7 for all C items 0 0	0 7 See Note 0	7 for all C items 0 0	7 for all C items 0 0	High New Mod Retro
C-15	Training: TAA Opportunities: Competence in use of all TAA systems.	See Note	7 for all C items 0 0	0 7 See Note 0	7 for all C items 0 0	7 for all C items 0 0	High New Mod Retro
C-16	Training: TAA Opportunities: Train new IMC escape procedures using autopilot and parachute.	See Note	7 for all C items 0 0	0 7 See Note 0	7 for all C items 0 0	7 for all C items 0 0	High New Mod Retro
C-17	Training: TAA Limitations: TAA judgment training.	See Note	7 for all C items 0 0	0 7 See Note 0	7 for all C items 0 0	7 for all C items 0 0	High New Mod Retro
C-18	Training: TAA Limitations: Train to avoid over-estimating capabilities.	See Note	7 for all C items 0 0	0 7 See Note 0	7 for all C items 0 0	7 for all C items 0 0	High New Mod Retro
C-19	Training: TAA Limitations: “How to Kill Yourself with TAA Avionics”.	See Note	7 for all C items 0 0	0 7 See Note 0	7 for all C items 0 0	7 for all C items 0 0	High New Mod Retro
C-20	Training: Risk Management: TAA Risk Management Training.	See Note	7 for all C items 0 0	0 7 See Note 0	7 for all C items 0 0	7 for all C items 0 0	High New Mod Retro
C-21	Training: Risk Management: Proper Selection of Airplane for Pilot and Mission.	See Note	7 for all C items 0 0	0 7 See Note 0	7 for all C items 0 0	7 for all C items 0 0	High New Mod Retro
C-22	Training: Risk Management: Guidance to Pilots on when Instrument Rating is Needed.	See Note	7 for all C items 0 0	0 7 See Note 0	7 for all C items 0 0	7 for all C items 0 0	High New Mod Retro
C-23	Training: Risk Management: Combined effects in faster TAAs.	See Note	7 for all C items 0 0	0 7 See Note 0	7 for all C items 0 0	7 for all C items 0 0	High New Mod Retro
C-24	Training: Risk Management: Lower pilot experience in high capability airplane.	See Note	7 for all C items 0 0	0 7 See Note 0	7 for all C items 0 0	7 for all C items 0 0	High New Mod Retro
C-25	Training: Risk Management: Older Pilots in computer-intensive airplanes.	See Note	7 for all C items 0 0	0 7 See Note 0	7 for all C items 0 0	7 for all C items 0 0	High New Mod Retro

D-1	Others: Accident Investigators: NTSB extract flight data from avionics.	?	8 0 0	8 0 0	8 0 0	8 0 0	High
D-2	Others: Instructors-Examiners: Instructors must teach, and examiners must test in the use of TAA systems.	8 0 0	8 0 0	8 0 0	8 0 0	8 0 0	High
D-3	Others: Insurers: Insurance incentives for minimum and advanced TAA training.	8 0 0	8 0 0	0 8 0	8 0 0	8 0 0	High
D-4	Others: Owner-Pilot Organizations: Owner-pilot organization model-specific training and safety programs.	0 8 0	8 0 0	0 8 0	8 0 0	8 0 0	High
D-5	Others: Shared-Ownership Organizations: Contractual additional training requirements.	8 0 0	8 0 0	0 8 0	8 0 0	8 0 0	High
D-6	Others: Accident Investigators. Avionics Record Button Pushes.	?	8/0 0 0/8	8/0 0 0/8	8 0 0	8 0 0	High new Low Retro
D-7	Others: Accident Investigators. Cameras, data storage.	?	8 0 0	8/0 0 0/8	8 0 0	8 0 0	High new Low Retro

Notes:

A-1. The most beneficial weather graphic for GA safety is IFR conditions. There is now no such graphic, but the AWRP program has a program to develop C&V, to produce a graphic in 2-3 years. AOPA/ASF: Current effectiveness 1 without, 2 with it. Within 3 years, C&V graphics will not be available widely.

A-3. To be effective, it needs to be correlated to airplane performance, and show a red density altitude number when a problem.

A-4. Different cost and engineering implications for OEM vs. retrofits.

C-2. General problem of reduced effectiveness of additional training because of inconvenience, time and cost. Financial feasibility in training is correlated to the value of the airplane, with lower feasibility for retrofits generally than OEMs. On the average, for OEMs, 2, for retrofit 1. The key is making training cheap and easy and providing incentives for it.

C-5. This applies equally to non-TAAs. Additional training to master the "mental airplane", to deal with the complexity of operating all the features of the avionics, is the price for easier operation every day.

C-7 to C-10.

D-2. Global requirements. 350 hours TT, IFR, plus either 25 hours MM with a COPA recommended flight instructor (25 total, ½ Cirrus trained and the rest trained by these, Cirrus will have factory-recognized instructors based on training at Cirrus, and they will be available at 4 satellite sites. Many instructors want to get this status, and insurance companies are also approving these instructors), or factory-authorized instructor training, and UND is training properly. Other top insurers have same or similar requirements. Second and third tier insurers, offering lower liability limits probably have requirements. But for expensive TAAs, there are too few airplanes in the market place compared to the number of accidents. The safety record of TAAs may change as the number of aircraft in the market place increases. This is driven by the performance of the airplane, not the TAA systems. Some persons are self-insured and non-financed. No FAA requirements required. For an OEM TAA, the problem is resolved through these systems.

For a retrofit, there is a problem. Insurer would not know if TAA systems are installed, even if the value of airplane increases. An older airplane retrofitted to TAA status would not require additional special training. How much new equipment in the old-tech airplane will trigger an additional instructor requirement? The PTS now requires that pilots be able to use all the installed equipment. GPS navigators are the training problem, not PFD or MFD, but instructors may not be familiar with the navigator that is installed.

There are 80,000 CFIs, not all are active. Instructors could be required to have at least become familiar with the top three navigators based on CD ROM, instructor log-book entry that completed CD ROM course.

D-3. Insurers need claims and accident data that demonstrate that superior pilot training results in a higher safety record. Therefore, the insurance market might consider lower premiums for pilots receiving superior training if the training results in a better safety record.

D-4. Effective to extent pilots participate. COPA has 50% of owners are members, 80% of members are or will participate in training. Manufacturers can encourage pilots to join their type-clubs.